THE NATIONAL GEOGRAPHIC MAGAZINE

Vol. XIII JULY, 1902 No. 7

MARTINIQUE NUMBER

CONTENTS

PAGE

REPORT BY ROBERT T. HILL ON THE VOLCANIC DISTURBANCES IN THE WEST INDIES. ILLUSTRATED . . . 223

THE RECENT VOLCANIC ERUPTIONS IN THE WEST INDIES. BY ISRAEL C. RUSSELL. ILLUSTRATED 267

VOLCANIC ROCKS OF MARTINIQUE AND ST VINCENT. COLLECTED BY MESSRS HILL AND RUSSELL. DESCRIBED BY J. S. DILLER 285

CHEMICAL DISCUSSION OF ANALYSES OF VOLCANIC EJECTA FROM MARTINIQUE AND ST VINCENT. BY W. F. HILLEBRAND 295

REPORTS OF VESSELS AS TO THE RANGE OF VOLCANIC DUST. COMPILED BY JAMES PAGE 298

Published for the National Geographic Society
By McClure, Phillips & Co., of New York

$2.50 a Year REPRINT 25 Cents a Number

Entered at the Post-office in Washington, D. C., as Second-class Mail Matter.

THE NATIONAL GEOGRAPHIC MAGAZINE

AN ILLUSTRATED MONTHLY, published for the NATIONAL GEOGRAPHIC SOCIETY, of Washington, D. C., by McCLURE, PHILLIPS & Co. All communications should be addressed to the Managing Editor of the NATIONAL GEOGRAPHIC MAGAZINE, Corcoran Building, Washington, D. C. Business communications may also be addressed to McClure, Phillips & Co., at 141 East 25th St., New York City.

25 CENTS A NUMBER; $2.50 A YEAR

Editor-in-Chief: HENRY GANNETT
Chief Geographer, U. S. Geological Survey

Managing Editor: GILBERT H. GROSVENOR

Associate Editors

GENERAL A. W. GREELY
Chief Signal Officer, U. S. Army

W J McGEE
Ethnologist in Charge, Bureau of American Ethnology

C. HART MERRIAM
Chief of the Biological Survey, U. S. Department of Agriculture

DAVID J. HILL
Assistant Secretary of State

ELIZA RUHAMAH SCIDMORE
Author of "Java, the Garden of the East," etc.

MARCUS BAKER
U. S. Geological Survey

WILLIS L. MOORE
Chief of the Weather Bureau, U. S. Department of Agriculture

O. H. TITTMANN
Superintendent of the U. S. Coast and Geodetic Survey

O. P. AUSTIN
Chief of the Bureau of Statistics, U. S. Treasury Department

DAVID T. DAY
Chief of the Division of Mineral Resources, U. S. Geological Survey

IDA M. TARBELL
Author of "Life of Napoleon," "Life of Lincoln," etc.

CARL LOUISE GARRISON
Principal of Phelps School, Washington, D. C.

WASHINGTON, D. C.

VOL. XIII, No. 7 WASHINGTON JULY, 1902

THE NATIONAL GEOGRAPHIC MAGAZINE

REPORT BY ROBERT T. HILL ON THE VOLCANIC DISTURBANCES IN THE WEST INDIES

WASHINGTON, D. C., *June 24, 1902.*

DR. ALEXANDER GRAHAM BELL,
President National Geographic Society.

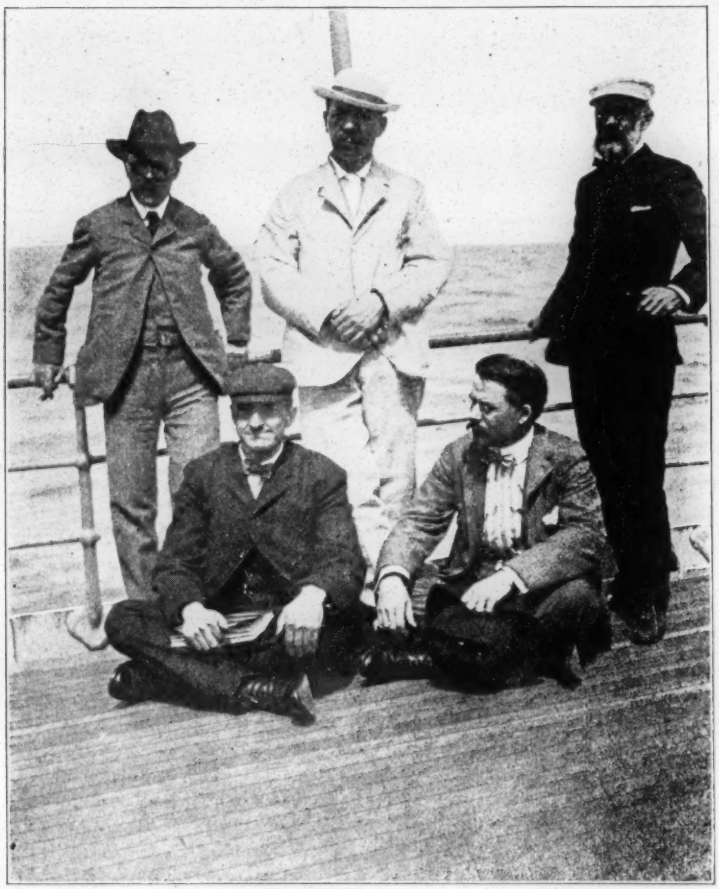
DEAR SIR: I transmit herewith my report on my investigations of the recent volcanic eruptions of Mont Pelée, Island of Martinique. I had previously made two visits to the island and was somewhat familiar with its topography and geology. My researches consisted of ten days' study on the island, from May 21 to May 30, inclusive. Most of the time was devoted to studying the physiographic effects of the volcano, the nature of its eruptions and ejecta, and the procuring of evidence from eyewitnesses concerning the facts of the catastrophe. I traveled extensively over the surface and margins of the area of the disaster on foot and horseback and circumscribed the coast with boats.

During my stay I was placed under repeated obligations for courtesies extended by U. S. Consul Ayme, Captain McLean, of the U. S. cruiser *Cincinnati;* Lieutenant McCormick, commander of the U. S. tug *Potomac;* Admiral Servan and officials of the French fleet; Mr Ferdinand Clerc, the leading planter of the island, and innumerable members of the negro and colored peasantry, whose courtesy and hospitality were graciously extended on every occasion. Special thanks are due Captain Berry and all the officers and sailors of the *Dixie*, who by self-deprivation accommodated our party on their vessel. Thanks are also due Mr J. S. Diller and Dr George Steiger, of the U. S. Geological Survey, for their prompt petrographic examination and chemical analyses of the specimens collected, and for their prompt reports published elsewhere in this Magazine.

In the present article I have endeavored to present a technical statement of the actual events of the great eruption. The time has been too limited for me to thoroughly digest and interpret the data collected. Later I shall present some further remarks and my final conclusions on the phenomena in the Century Magazine for September. It is also but just to remark that the accompanying article does not pretend to be a complete or final presentation. I appreciate that my associates, Professors Russell and Jaggar, who accompanied the *Dixie*, and Professor Heilprin, who arrived on the island as I was leaving, all collected information and data equally as valuable as mine, and that they may have deductions of greater importance.

Very truly yours,

ROBERT T. HILL,
Geologist, U. S. Geological Survey.



Robert T. Hill C. E. Borchgrevink Israel C. Russell
Thomas A. Jaggar E. O. Hovey

On Board the *Dixie*

Messrs Hill and Russell contribute to this number their preliminary reports to the National Geographic Society. It seemed best that one of the geologists of the National Geographic Society expedition should remain in the region of volcanic disturbance. Dr Thomas A. Jaggar, who is professor of geology in Harvard University, was therefore commissioned by the Society to continue his researches, and his report will be published later in this Magazine. Lack of space prevents our publishing Mr Borchgrevink's report in this number. Dr E. O. Hovey, a member of the National Geographic Society, represented the American Museum of Natural History.

G. H. G.

THE DEPARTURE

THE Lord rained fire and brimstone and the smoke of the country went up as of a furnace.—Bible.

The present year seems to be one of unusual volcanic and seismic activity. In Russia, Mexico, Guatemala, the West Indian and Aleutian Islands disturbances of severity, accompanied by great loss of life, have taken place, while the volcanoes of Vesuvius and Hawaii are also displaying marked activity. It was reserved for two apparently quiescent and long-forgotten volcanoes in the West Indies, however, to give us an exhibition of sudden and deadly violence, and to awaken a world-wide interest in these phenomena.

The first news of the outburst of the Martinique volcano to reach the United States was a dispatch May 6 from St Thomas, West Indies, to the *New York Journal*, announcing that the flow of lava from the volcano Montagne Pelée, Island of Martinique, had begun, and on the previous Saturday, May 3, had completely destroyed the Guerin factory, situated two miles from St Pierre, the principal town of Martinique, and reporting that there was a rumor to the effect that 150 persons had disappeared.

On May 9 the frightful news followed, announcing that the beautiful city of St Pierre, with all its inhabitants, had been annihilated on the preceding day by a terrific volcanic outburst.

As horrible as are volcanic disasters, they are always exaggerated in the first reports, and many were loath to believe that 30,000 people had been swept into eternity at a single moment, as was described.

Sitting in my office, where at the time I was preparing a long-deferred report upon the geology of the Windward Islands for Professor Alexander Agassiz, to be published by Harvard University, the news was made known to me by a reporter of the *New York Herald*, who asked me to give him some information (published in the *Herald* of May 10) upon the geology of the islands and the volcanoes. From that moment until the sailing of the *Dixie*, at 9 p. m. on the night of May 14, when she sailed from the Brooklyn dock, I was besieged by reporters for information, and since that first news I have myself been in a continuous state of eruption from endeavoring to procure and give such information as within my power.

THE START

On Tuesday, May 13, the officers of the National Geographic Society requested me to accompany the *Dixie* relief expedition, which sailed at the hour previously stated. Without preparation I joined the ship, and on the morning of the 15th was well out to sea, headed for the scene of disaster.

We had hardly settled ourselves on board the man-of-war when we began to speculate concerning the conditions which we would find awaiting us at the island. Immediately following the news of the catastrophe at St Pierre the reports were full of accounts of many startling phenomena. Among these may be mentioned the rumors that the top of the mountain had blown away; that the island had decreased in area one-half; that the entire north coast had disappeared; that the sea bottom had sunk 1,000 feet; that the streams of lava were flowing, and that the configuration of the entire island had been changed. Finally, as we left New York, the afternoon papers printed rumors that Fort de France had been burned, so that for seven days we sailed in ignorance of the conditions awaiting us.

From all parts of the world also came notices of impossible accompanying phenomena. Volcanoes were found in Ne-

braska and upon the sedimentary islands of Alaska. Earthquakes were reported from Asia to South America; red sunsets seen in distant lands; floating bodies and débris picked up far from the scene of the disaster. Even recently it has been reported that the surface of Pennsylvania had caved in since the disaster, and that the enthusiastic crank who discovered this fact was coming to Washington to see if the national capital had not suffered a similar subsidence. Fortunately we found that most of these reports were founded upon imagination or over-enthusiasm, and upon their face are as apparently incredible as were the reports of two floating islands inhabited by hordes of monkeys and green parrots reported to have been seen on the Gulf by the facetious editor of a Washington paper.

It will be impossible for me in the accompanying paper to take up each rumor and dissect it specifically; but I shall endeavor to present every fact which has come under my observation or been recorded by me from the lips of authentic witnesses, leaving to the end the presentation of deductions concerning the immediate cause of the disaster.

GENERAL GEOGRAPHY OF THE WINDWARD ISLANDS

In order to fully understand the catastrophe it will be necessary to present a brief review of the geography and geology of the region.

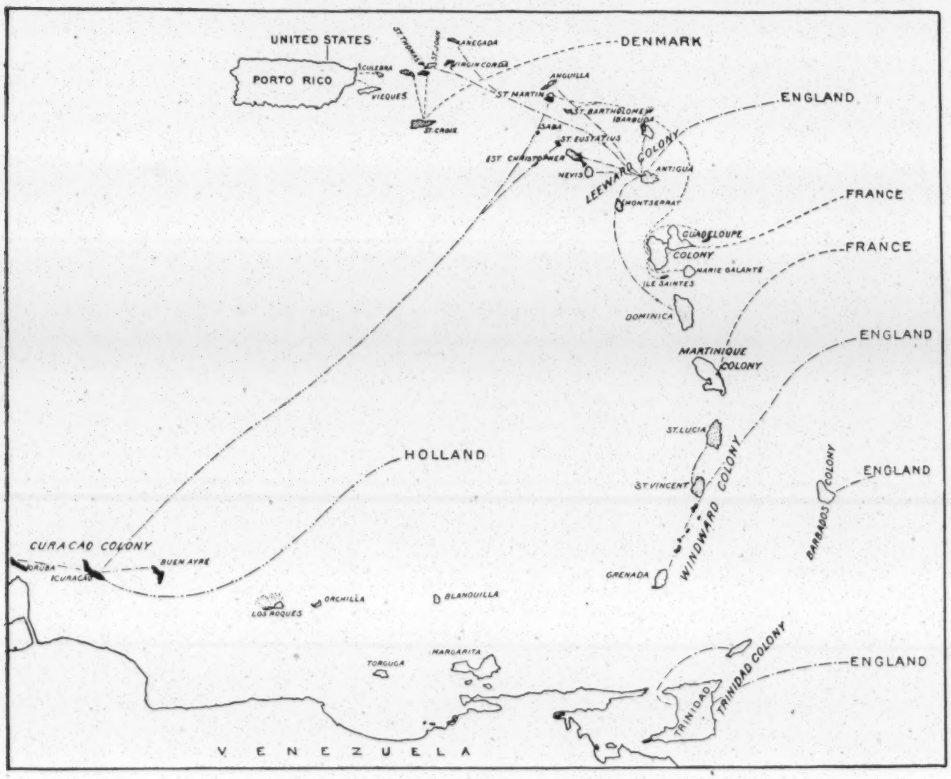
Across the throat of the Caribbean extends a chain of islands (the Caribbees), which are really smouldering furnaces, with fires banked up, ever ready to break forth at some unexpected and inopportune moment. This group, commencing with Saba on the north, near our own Porto Rico, and ending with Grenada on the south, near Trinidad, consists of ancient ash (lapilli) heaps, piled up in times past by volcanic action. These old ash heaps have weathered into fertile soil, which, bathed by an undue share of moisture, has become covered with ripe growths of damp and mouldering vegetation. This same soil produces all the richest vegetable products of the Tropics.

In three previous papers I have given descriptions and classifications of the geologic, geographic, and political conditions of the West Indies. In the first of these, "The Geology and Physical Geography; study of a type of Antillean development based upon surveys made for Alexander Agassiz," * I endeavored to give every fact concerning the complicated geological structure of the many types of islands, together with the more or less complicated physiographic history of how they are made and the changes which they have undergone. In the second work, "Cuba and Porto Rico, with the Other Islands of the West Indies," * a popular geographic story of the islands, their resources and their people, was presented. The third article, entitled "The Broken Necklace," in the *Century Magazine* for April, 1901, endeavors to relate the unhappy conditions which have brought the islands into a state of economic ruin.

To those who first look at the map and have not considered their minute geology, the Lesser Antilles appear as the members of a kindred archipelago. The Virgin Islands at the north are Antillean, while all south of Grenada are South American in natural relations. Even after detaching their termini the remaining islands of the archipelago lying between the Anegada Passage and Tobago, constituting the Windward group, present almost as complicated composition. Some of the northern islands, such as Santa Cruz and St Bar-

* Bulletin Museum of Comparative Zoölogy, Harvard College, parts v and vi, Sept., 1899.

* The Century Company, New York, 1898, second edition, 1900.



Political Map of Windward Islands

tholomew, are also Antillean in structure, and were it not for the deep Anegada Passage, which almost severs the latter from the submerged platform at the north end of the Windward Channel, they might probably be considered Antillean.

All the Windward Islands with the exception of Barbados probably have a base of volcanic rock, notably St Martins and Antigua of the outer chain. The Windward Islands constitute a unique and peculiar geologic province, the discussion of which, with their general phenomena, can now be briefly considered.

The islands of the chain, however, south of the Anegada Passage and north of Trinidad, constitute a different geologic type, which may be classed by composition into three general subtypes as follows: (1) Volcanic islands composed almost entirely of igneous material; (2) islands composed, at their surface at least, of organic oceanic sedimentary débris, and (3) compound islands, with a higher summit region of volcanic rocks of the first-mentioned class, with added areas or benches of sedimentary rocks. These three types are exemplified in Martinique, Barbuda, and Antigua.

WINDWARD GROUP

The Windward group is divisible into two parallel belts extending the length of the archipelago. The eastern belt,

composed of the sedimentary and compound type, includes Sombrero, Dog, Anguilla, St Martin, St Bartholomew, Barbuda, Antigua, the Grande-Terre of Guadeloupe, Marie Galante, and Desirade.

The inner belt facing the Caribbean includes Saba, St Eustatius, St Christopher, Nevis, Monserrat, Basse-Terre, Guadeloupe, Dominica, Martinique, St Lucia, St Vincent, the Grenadines and Grenada constituting the newest and highest summits of the Windward group, attaining heights approximating 5,000 feet in all the islands mentioned except the two most northern, Saba and St Eustatius, which rise 2,820 and 1,950 feet respectively, and the Grenadines.

GEOLOGY OF THE ISLANDS

The configuration and structure show that their history extends back to considerable antiquity. In the first place, while the primary configuration of all these islands is constructional—largely due to extrusive piling up—the present minor details of configuration, expressed in steep coastal bluffs, benches, slopes, and canyons, are modified by erosion, which has required considerable time for development. True crater shapes, except in St Eustatius, Nevis, and St Christopher, are inconspicuous, and are merely secondary summit features in the other islands, occurring parasitically upon masses of old eroded volcanic débris reaching a height of 4,000 feet, which have lost the features of their original contour through erosion. Secondly, the islands are all composed largely of vast piles of old tuffs and trachytic or andesitic débris of many eruptive epochs, like the volcanic heights of the Costa Rican plateau, which indicate long continuation of the vulcanism since comparatively remote geologic epochs, reaching back most probably to Eocene time.

This main or interior chain is composed of piled up volcanic débris, and upon the islands of Guadeloupe, Martinique, and St Vincent there have been active volcanic eruptions in historic time, 1797 in the former and 1812 in the latter. Soufrières, hot springs, etc., show that this activity is only slumbering quiescent in nearly all these islands. Besides, most of them still possess upon their summits one or more true craters, while Saba and St Eustatius are composed of simple crater cones now quiescent. While these facts attest recent eruptivity in the islands, there is much evidence presaging the conclusion that the present vulcanism is merely the survival of that which began earlier in geologic history, and that the main mass of the material composing the islands was ejected long before the dawn of human history.

True elevated reefs—normal, unaltered reef rocks raised by epeirogenic elevation to heights not exceeding 100 feet above the sea—do not occur near sea-level in the Leeward margin of the inner belt of the Caribbee Islands.

In St Christopher, St Eustatius, Guadeloupe, Martinique, St Lucia, and Grenada disturbed fossiliferous beds of Pleistocene or recent age are exceptionally found interbedded in volcanic débris of the lower slopes at altitudes of two or three hundred feet above the sea, showing that uplifting as well as extrusion has in part produced the present eminences, and that vulcanism existed in or prior to Pleistocene time. The fossils enumerated are hardly older than Pliocene and are most probably Pleistocene, and their border-like position shows that the greater mass of the islands were ejected in previous epochs.

So much for the main chain of the Caribbees considered by themselves; but the eastern belt, of the compound type, owe their present position above the sea-level to the epeirogenic uplifts which affected the Caribbean area in later geologic time.

In Guadeloupe we have much evidence concerning the evolution of the volcanic range and the mass of sedimentaries. This island is composed of two parts, of about equal area, separated by a shallow creek or strait, Rivière Salée. The most western of these islets (Basse-Terre) is a typical volcanic pile of the main Caribbee chain and is thoroughly mountainous. The most eastern area (Grande-Terre) is an elevated constructional plain, composed of sedimentary formations of Pleistocene age, underlain by a platform of volcanic tuffs, etc. Still to the eastward of Grande-Terre is the small terraced island of Desirade, composed entirely of organic material, which, with several other islets, stands above a shallow submerged platform extending out from the southeast end of Grande-Terre and Basse-Terre. To the southward of Grande-Terre is the island of Marie Galante, of the same topographic and geologic type as Grande Terre.

Moreau de Jonnes, in 1816, discovered that even these calcareous outer islands of the Caribbee chain rested on igneous formations. He showed that the calcareous islands were all situated externally to the windward of the volcanic shore, and that even in the volcanic islands where calcareous formations were also found the latter were always on the Atlantic side. In fact, there is evidence that the line of volcanic activity has migrated westward slowly during geologic periods.

Concerning the origin, relation, and succession of volcanic events the following facts can be stated: In late Cretaceous time vulcanism was active in the now quiescent regions of the North Mexican and Trans-Pecos Cordilleras, the Coastal Plain of Texas, the Isthmus of Panama, and the Great Antilles, Jamaica then being a volcanic island. The late Cretaceous limestones of Costa Rica contain angular specks of volcanic material intermixed with them, as also do the late Eocene sediments of Panama, which facts lead us to believe that the present Central American volcanic plateau has been an intermittent locus of volcanic activity from the Cretaceous to the present, as also has the volcanic region of Mexico.

The volcanoes of the Windward Islands, in my opinion, date back to at least the Eocene. Later in the Miocene vulcanism became quiescent in the great Antilles, but continued in the four great loci of present activity—Southern Mexico, the Northern Andes, Central America, and the Windward Islands. In the last two regions mentioned the greater masses of the present volcanic heights were piled up before the Pliocene, and the present craters are merely secondary and expiring phenomena.

Synchronously with the regional uplifts of late geologic time, volcanic piling has continued on the mainland and in the Windward Islands, although the mass of ejecta during these later days is Lilliputian in comparison with the great heaps of débris piled up in preceding epochs. The present craters and vents of the Mexican, Costa Rican, and Windward summits are mere ant-hills capping older mountains of ejecta. The last volcanic fires of the Cordilleran region of Northern Mexico and the United States expired in Pleistocene time.

CARIBBEE VOLCANOES*

It has been so long since any explosions have occurred in the Caribbee Islands that most geographers as well as the inhabitants were of the opinion that

* It is one of the most lamentable admissions of our lack of geographic knowledge to state that no traveler, geologist, or explorer has ever systematically visited all these vents and craters or published anything upon them as an entirety. I must confess that in my own studies of the islands there were more difficult problems of paleontology, stratigraphy, and physiography throwing light upon their evolution and history, which occupied my time and attention.

the forces which produced them were spent, and classified them as extinct volcanoes. Hurricanes, plagues, misgovernment, and French-English wars played frequent havoc with these people, but the calamity resulting from the explosion of these volcanoes is one of which they hardly dreamed. They looked upon the verdure-clad slopes only as the home of the sprites and goblins which abound in their peculiar folklore, and of the dreaded *fer de lance*, one of the most fatal serpents in existence, which inhabits only the islands of Martinique and St Lucia. Even the previous eruptions in Guadeloupe and St Vincent and Martinique in 1851 had not disturbed their faith in the perfect security of the beloved mornes.

Within human history there have before been but two serious eruptions in the Caribbee Islands, and both of them were in St Vincent (1718 and 1812), but one of the latter, like the present catastrophe, was one of the most appalling and destructive the world has ever seen. In 1812 the mountain of Morne Garon, on the Island of St. Vincent, about 90 miles south of Martinique, erupted. The explosion was a most fatal and far-reaching cataclysm, being equaled in recent years only by that of Krakatoa, in the Straits of Sunda. It was preceded by earthquakes. In Caracas 10,000 persons were buried in a single moment, and after this great event ruin was wrought all along the line of the Andes by earthquakes.

All down the range of the Antilles from Saba to Grenada there is hardly an island without its "soufrière" or solfatara—the crater, it would seem, of some volcano whose eruptive energy has dwindled into that milder form. Some of these soufrières are wholly or almost extinct, and have subsided into mere yellow-tinged ashpits, where perhaps the scanty thread of light vapor or a tepid spring finds its way through the surface. Others again are still active.

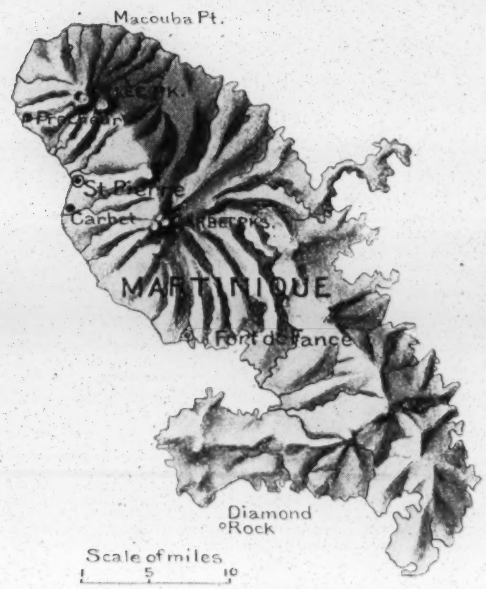
The soufrières or craters of the Caribbee Islands are not symmetrical cones sloping within to a central vent, but are of the type known as calderas—that is, broad flat basins within the area of a larger broken encircling rim, marked by vents with more or less sub-vertical walls, exhibiting the stratified layers of ejecta of former explosions. The walls of the vents or pits are destructional and not constructional, as are the walls of typical lapilli and lava cones.

Although called quiescent, the volcanoes of several of the Caribbee Islands have shown more or less evidence of continuous activity. The soufrières of Guadeloupe and St Lucia and Mt Misery on St Kitts have almost continuously ejected small jets of steam; the "Boiling Lake" of Dominica may also be considered as a volcanic manifestation. Numerous hot springs on most of the islands also indicated the presence comparatively near the surface of great heat in the rocks.

The northern islands of the necklace, like Saba and St Eustatius, are simpler volcanic piles with dominating crater cones, but the center of the chain consists of five larger islands—Guadeloupe, Dominica, Martinique, St Lucia, and St Vincent—each of which is a complicated mass of ancient combined constructional and destructional forms, accompanied by a few volcanic vents, whose peaks attain their greatest height in Mount Diablotin in Dominica.

The Island of St Eustatius, 2,000 feet in altitude, is a typical crater form and is surrounded by a depression called the Punch Bowl.

St Kitts is dominated by Mount Misery, with a summit crater 1,000 feet deep which is a lake in the rainy season. Hundreds of fissures in the flank of the mountain continue to emit solfataric sulphurous gas. Montserrat has two culminating peaks. One of these is a cone called La Soufrière, from which hot vapors still erupt.



Sketch Map of Martinique

THE VOLCANOES OF GUADELOUPE

The western Island of Guadeloupe has four lofty igneous cones—Grosse-Montagne (2,370 feet) in the northwest, whence radiate various ridges nearly at the same elevation; the Deux Mamelles (2,540), with La Soufrière (4,900) farther south, and toward the southern extremity the Caraibe (2,300), with Houelmont (1,800). These various masses merge in an irregular sinuous range, whose watershed has been incessantly modified by the erosive action of the tropical rains.

Solfataric igneous energy is still active in Guadeloupe at one or two points, such as Bouillante, at the foot of the Mamelles on the Caribbean Sea, where little craters in the sands emit hot vapors and warm waters bubble up in the sea; even in the sea gas bubbles rising from the marine bed are often seen bursting on the surface. The supreme crest of La Soufrière stands in the center of a plain which was probably a crater and which still discharges sulphuretted hydrogen. A circle of crests incloses the Petite Plaine, a depression which also represents an old crater. Gas continues to escape from a deep fissure in the center, which contains the sulphur deposits whence the mountain takes its name. Numerous thermal springs flow from the outer slopes.

The Islands of Les Saintes, a group of rocky headlands south of Guadeloupe, represent the scene of another prehistoric explosion in the Caribbean chain. These islets are the fragmentary remains of two volcanoes which were disposed in the same direction as those of Guadeloupe and Dominica. Of the seven separate rocks some are fractured craters, others are lapilli heaps resting on a submarine volcano, the highest point being Le Chameau (1,040 feet), in Terre-de-Haut, on the east side of the group. In the Les Saintes, according to personally communicated information from U. S. Consul Louis M. Ayme, there are large bluffs of alum, which are the product, no doubt, of sulphurous vapors, SO_2, acting on alumina.

THE BOILING LAKE OF DOMINICA

Mont Diablotin, the culminating point of Dominica, rivals the Grand Soufrière of Guadeloupe in altitude, and according to Bulkeley, who gives it a height of 5,340 feet, it is the most elevated summit of the whole range of the Lesser Antilles. The Grand Soufrière near its summit is one of the largest of all the quiescent craters of the Caribs. Several smaller and more accessible soufrières are scattered throughout this highly volcanic island. A cloud always hovers above the Grand Soufrière.

Diablotin stands at the northern ex-

tremity of the island, overtopping by about 2,500 feet an old crater in the interior, which till recently was still flooded by a "boiling" lake—that is, heated by thermal springs bubbling up from the bottom, and every five minutes upheaving the waters in a foaming column. Within a short distance of the margin the tarn was no less than 300 feet deep. In 1880 great landslips took place, new craters were opened in the hills, the columns of water disappeared, and the lacustrine basin lost much of its beauty. The fissures emitting gases were continually shifting their position, and the rivulet flowing from the lake was swollen along its course by springs of sulphurous water descending from crevasses in the upland valley.

The boiling lake of Dominica is a great caldera surrounded by precipitous cliffs several hundred feet in height, at the bottom of which is a large valley, originally reeking with thick white sulphur vapor, which turned black every article of silver carried on the bodies of persons who overlooked it. The soft bed of lapilli that paves the floor of the caldera is incrusted with sulphur in spots, from which rises a mixture of boiling water and steam, making a constant tumult of noises. The waters—white, black, and red in color—rush out in a strong torrent, scalding hot.

A traveler describes this caldera as fenced in by steep perpendicular banks or cliffs, varying from 60 to 100 feet high, cut out of ash and pumice. In the bottom of this was a giant seething caldron, which raged and roared like a wild beast in a cage. Toward the center, where the ebullition was fiercest, geyser-like masses were thrown up to a height of several feet, not always from the same spot, but shifting from side to side, each burst being preceded by a noise like the firing of a cannon. The heat of the water was 185° Fahrenheit. The height of the lake was a little over 2,400 feet above the sea.

The volcanic phenomena of Martinique, which are the subject of this article, will be more fully described in the succeeding pages.

The crater at St Lucia known as Sulphur Mountain has an elevation of 1,000 feet and covers about four acres; the sides are barren and covered by deposits of sulphur. In the days of French possession a sanitarium was built around the boiling springs of its northern slope.

This volcano, 4,000 feet high, is still active, and in the chasms of its crater, lined with deposits of sulphur, the eruptive matter is constantly in a state of ebullition. Copious thermal waters bubble up in various parts of the island and one of the sulphurous streams still flows through a half-ruined establishment erected by the French before the Revolution. This soufrière occupies the floor of a steep crater cone and is pierced by a dozen large calderas, circular in form, 4 to 16 feet in diameter, each boiling furiously, one with coal-black water, another with milky white, a third with gray mud, a fourth with a mixture of all these, while the countless apertures, some barely an inch across, send up steam or hot water in noisy jets, and have done so since the first memories of the earliest colonists, nearly three centuries ago.

ST VINCENT BEFORE THE LAST ERUPTION

That St Vincent is volcanic is apparent from recent events, the relation of which must be left to those who are studying it, my recent visit having been confined to Martinique.

Before the present eruption the summit of La Soufrière, at the northern end of St Vincent, was 3,500 feet above sea-level, and had two craters. The first was three miles in circumference and 500 feet deep, and was separated from what is known as the new crater

(of 1812) by a ridge of igneous material. This is a mere fragment of an ancient cone which, it is said, probably at one time rose to double the present height of the loftiest summits of the crater. Reports, contradictory in their details, all agree in the general statement that in the year 1718 a terrific eruption of La Soufrière buried the whole island and surrounding waters in ashes; it was, doubtless, on that occasion that the upper part of the cone was blown away. The ruptured mountain was still in a restless state in 1785; but in 1812 a deep lake flooded its terminal crater. The waters were agitated by frequent shocks, which corresponded with similar disturbances occurring simultaneously in both Americas and the Antilles.

During the year 1812 Morne Garon vomited vast clouds of dust which darkened the sun for an entire day and spread over a hundred miles of sea and land. The volumes of mud changed the configuration of the island, as well as its eastern end. The present crater, formed at that time, is half a mile in diameter and 500 feet deep, and is now a beautiful lake, walled in by rocky cliffs to a height of 800 feet. Its slopes have been re-covered with peaceful vegetation and fields of cane until the beginning of May last.

The volcanic uplands, culminating in a peak 2,750 feet high, were clothed with forest growths, which here and there reveal the mud streams and prismatic colonnades terminating in superb cliffs on the coast. Still open craters occur in several places, and two romantic lakelets, fringed with bamboo and tree ferns, are also probably flooded volcanic cones. Pleasant villas and country-seats are scattered over the valleys and on the slopes of the hills in the midst of verdant thickets and flower gardens. None of the Antilles surpass Grenada in sylvan charms, wealth of color, and fragrant blossom.

MARTINIQUE

GENERAL GEOGRAPHY

The surface of Martinique, about 380 square miles in area, is exceedingly mountainous and rugged. The island is irregular in outline. Its greatest length, north to south, is 49.6 miles; the greatest width, 18.6 miles. Its northern and western coast lines, except where the latter is indented by the great Cul dé Sac or Fort de France Bay, are comparatively regular, but the eastern or windward coast is broken into numerous peninsulas, islands, and headlands by the erosive action of the strong surf driven by the trade winds against that shore.

In general, while all of the island is of rugged configuration, it may be divided into two conspicuous subdivisions by drawing a line north and south from the mouth of Lazard River, near the eastern extremity of Fort de France Bay, northward through the village of La Trinite. The Rivers Lazard and Galion separate the two divisions, and by encroachment will soon completely capture the slight divide now existing between them, and perhaps some day in the future separate Martinique into two divisions as Guadeloupe is now separated.

To the east of this line and south of the Bay of Fort de France, the country is comparatively less rugged, although still mountainous, and has a more ancient and degraded configuration.

The southern division of the island does not rise anywhere to the heights of the northwestern, the culminating point being Mont Vauclin, 1,567 feet.

This portion has lost most of its original constructional forms, and its ridges and valleys are principally the work of destructional erosion. The eastern

border of this area between the long peninsula of Caravelle on the north and Portes-d'Enfer is cut into hundreds of shallow bays and inlets by the strong action of the heavy surf which everywhere on that side prevents free navigation, and the contour and topography of the adjacent sea border shows that this land once extended to the outer margin of the islands which now border it.

All the country north of the Bay of Fort de France and to the west of this line, geologically speaking, may be considered a newer configuration—a later geologic addition to the island—which preserves much of its original volcanic constructional form, dominated by two commanding subcircular central volcanic mountains, the northernmost of which is Montagne Pelée and the other the Pitons du Carbet.

The topography of this northwestern area is chiefly constructional, the peaks of Pelée and Carbet being original volcanic cones, while many of the sloping salients between the streams radiating from them to the sea are old cuestas of ejecta. Destructional processes, however, are also strongly evident in the erosive dissection of the old craters and of the valleys or fonds.

While Pelée and Carbet are apparently twin volcanoes, the latter is the older of the two, and, judging from the broken nature of its surrounding crater bowl, has been extinct from time immemorial. Its altitude is 3,960 feet.

Montagne Pelée, at the north end of the island—a little to the west of its north-south axis—is a conical circular peak surrounded on three sides by water as if it had risen parasitic from the sea and had been united to the mainland by the débris of its southern flank. Of Pelée more anon.

The cone of Carbet, rising to a height of 3,960 feet, is undoubtedly the remnant of a high cinder cone now dissected into several peaks. Besides the major peaks mentioned, there are hundreds of rugged wooded hills, called mornes, some of which may have been old volcanic vents, while others are results of erosion.

Besides these major features of the configuration, there are several minor details which are of importance. The first of these is the rugged configuration of the mountains and fonds and the abrupt nature of the coast line, consisting everywhere, especially on the leeward side, except at the mouths of the rivers, of steep vertical cliffs. It is singularly ill adapted for safe harbors convenient to its population, and there are none except the superb bay of Fort de France, perhaps the best in the Windward Islands. On the windward side the coast line is rugged; but everywhere it is plainly to be seen that the work of the sea is constantly restricting the area of the island by the action of its waves.

Not only the eastern coast, but the entire perimeter of Martinique is being restricted by this destructional process. The horizontal action of the waves, which are everywhere undermining the coasts at water line, results in steep cliffs along the northern and western sides and many bights upon the eastern shore. Furthermore, this action has clearly left around the island a shallow submarine bench, which is especially marked along the southern and eastern coasts.

Another feature are the little elevated deltoid valleys of alluvium at the mouths of the rivers on the west, which constitute the plain upon which Fort de France is built. These, with the elevated reefs off the east coast, indicate uplifts as having taken place. Still a third feature are the evidences of an older and higher level of erosion back of the city of Fort de France.

The surface of the island is deeply scored by nearly 200 streamways, following the bottoms of deep V-shaped canyons which radiate from its summits to the sea. Seventy little perennial rivers descend from the mountains, but

only two of these are of any importance, the Rivière Lazard and the Rivière Capote. The valleys are justly termed fonds or depths.

Besides the numerous copious rivulets flowing into the sea, there are many warm springs in Martinique—the Fontaine-Chaude on the heights of Precheur, eight kilometers from St Pierre, the waters of Absalom, the springs near Didier, de Moutte, and of the Chain Bridge, places in the neighborhood of Fort de France. There are other springs not explored near l'Esperance, at Lareinty, Lamentin, and of the Frégate at François.

PEOPLE

The population of Martinique in 1894 was 189,500, or 470 people per square mile, all native with the exception of 1,307 born in France. These people, except a small sprinkling of white creoles, were colored or black, excepting a few Coolies, who had been brought from France. In general, the predominant population was a mixture of negro and European blood, with many peculiarities, which rendered them almost a distinct type. They were all, in comparison to the other West Indians, a well-to-do and prosperous people.

The principal cities of Martinique are Fort de France, population 17,274, and St Pierre, population 25,792. Besides these, there are many beautiful little villages along the coast. The town of La Trinite, on the east coast, is of considerable importance.

Fort de France, the capital, is of little or no commercial importance, being a political and social center. The place is of interest, however, and possesses the best dry dock in the Lesser Antilles.

St Pierre was the New York of Martinique, its social commercial metropolis and the center of all its industry and commercial life. Here were located all of the larger industries, including several large rum distilleries, ice plants, saw-mills, and furniture factories. It contained the two leading banks of the island—the Bank of Martinique and the English Colonial Bank.

If New York should be obliterated at a stroke, its loss to our country as a whole would not fall as severely upon us as has the loss of St Pierre upon the people of Martinique, for we have other coastal cities and harbors; but the entire commercial, financial, and business life of the Island of Martinique was centered at this place.

RAINFALL

The annual rainfall of Martinique averaged 150 inches on the coast and 350 inches on the mountains. The temperature shows no variation from day to day throughout the year, but is freshened by winds. The seasons show a slight variation from the normal West Indian type, and were divided into three, as follows:

1. *Saison Fraiche*, December to March; rainfall, about 475 millimeters.

2. *Saison Chaude et Seche*, April to July; rainfall, 140 millimeters.

3. *Saison Chaude et Pluvieuse*, July to November; rainfall, 1121 millimeters.

The surface of the whole island, except a few spots near the summit of Pelée and the fields of cane, is covered by dense woodland. Much of this woodland is culture, however, for it must be remembered that the people of the tropics live largely by tree products. A greater part, however, especially on the uplands, is primitive jungle of tree ferns, palms, plantain, and tropical deciduous trees. Besides the great estates of cane, mostly on the eastern side, there are many small plantations of yams, potatoes, and other tropical "provisions."

MONTAGNE PELÉE

Montagne Pelée is a circular cone culminating in a single summit peak from which the broken surface slopes

The City of St Pierre Before the Eruption

The ships have been careened on the beach by a hurricane

Photo by Israel C. Russell

The City of St Pierre After the Eruption

in all directions to the sea, except toward the south, where its constructional slopes meet those of Carbet and form a neck of land. This general plan is modified, however, by bold strokes of nature's erosive carving, whereby the surface is cut into numerous radial divides and canyons.

The crest is a steeper hill surmounting larger piles composed of pumice. The top was a truncated loaf, in the summit of which is a bowl-shaped basin, the floor of the old caldera, which has existed since prehistoric time. Around this rim bowl was a circle of pointed hills, of which Morne La Croix, the highest, stood about 200 feet above the caldera floor upon its southwestern edge. In the floor of the caldera was a lake called L'Etang de Palmistes. It measured 150 meters in circumference, and varied in volume. This floor of the caldera was covered with pumiceous soil, beneath which were mud and boulders of pumice-stone.

The perimeter of Pelée where it meets the sea, except from the southern edge of St Pierre to the mouth of the Rivière Blanche to the northward, is everywhere bordered by steep bluffs, as if it had been encircled by a trimming knife. The ten rivers which were their branching headwaters, originating almost at the summit, diverged toward the sea and cut the sloping surface into numerous triangular segments.

The surface of one of these segments lying toward St Pierre is relatively of lower altitude than those which surround it, and does not bluff upon the sea as the others do, although it is bordered by steep cliffs on the north and south of the Rivières Blanche and Mouillage respectively. The surface of this lower-lying segment between the opposing cliffs is in turn etched of several other streams and presents within itself a varied topography.

The boundary cliffs run nearly from the summit nearly to the sea, where they suddenly diverge at right angles, parallel to it, leaving little strips of beach between. This cliff-bound area is a great natural amphitheater. Upon one of these narrow lateral beaches at the south end the principal part of the town of St Pierre was built. In other words, St Pierre lay within the southern edge of the natural amphitheater, surrounded by steep cliffs and closely built against one of the latter. This is an important fact, which, should the explosive theory prove true, would explain much of the damage which has been wrought.

GEOLOGY OF MARTINIQUE*

Nowhere in the rocks of Martinique has there been discovered any evidence of sedimentary rocks derived from a preexisting land, such as are found in Barbados and the Great Antilles, and this fact, which is also apparent in the other volcanic Caribbees, strongly upholds the conclusion that these islands were built up from the sea bottom solely through the agency of piled-up volcanic ejecta.

The Island of Martinique is composed almost entirely of volcanic material. In addition to the volcanic rocks, there are two other types of formations which throw a great deal of light upon its geological history. These are, first, elevated estuary deposits of alluvial material at the mouths of its rivers on the west coast, and deposits of calcareous oceanic sediment resting upon a basement of older volcanic rocks eroding the east coast.

Along the southeast coast are some calcareous benches composed of material similar to that now forming off that shore, which have been elevated above the sea by epeirogenic movements. The

* The geology of Martinique has been published in detail by Moreau de Jonnes in 1814; Ch. Sainte-Claire-Deville in 1843. Recently Octave Hayot, of Martinique, published an essay on the subject.

calcareous formations are found notably at Sainte-Anne in the southwest peninsula of the island, which makes a great salient in the Strait of St Lucia, and of Vauclin to the windward of the main mass of volcanic rocks. The calcareous formations occur to the seaward of the igneous rocks not only in the vicinity of Sainte-Anne, but along the east coast through the districts of Marin and Vauclin almost to La Trinite. They form in this vicinity the eroded plateau of Pain de Sucre, and the Mornes of Cype, Bataille, Flambeau, and others, the summits of which are crowned by blocks of carbonate of lime, but one everywhere sees overlying volcanic rocks, which also occur in the Isle of the Table-au-Diable and Portes-d'Enfer.

The calcareous plateau or bench which forms the surface of the peninsula of Sainte-Anne is deposited on a *massif* of volcanic nature composed of a porphyry with white feldspar in a decomposed brick-colored matrix and very friable, owing to oxidation. These rocks are much jointed, like prismatic basalts. The superposed limestones have a thickness of 25 to 30 feet and are marked by horizontal bands. These calcareous formations are secondary and parasitic, however, for the main mass of the island is composed of volcanic material which has been piling up since the beginning of Tertiary time.

The volcanic rocks, which are predominantly of an andesitic nature, are of several ages and varieties. The older geological writings on the island, written before the present processes of classification had been adopted, classify them as trachytes, phonalites, and porphyries. The oldest of these are said to be trachytes of Miocene age, which are found in the southern peninsula. Reported as covering these are porphyroids, quartzites, porphyrites, and porphyries of Pliocene age in the central part of the island. The rocks so far mentioned are those exposed near the base of the volcanic piles. These are covered by great thicknesses of tuffs and later eruptive material, especially on the west side. The general surface of the volcanic rocks has also been thoroughly saturated by earth water and the minerals of their rocks decomposed, so that the rust line or zone of oxidation (regolith) is exceedingly deep.

The Pleistocene and recent eruptions seem to have been entirely of a pumiceous nature, and cover all the country to the north and notably in the Rivière Fallasse. Elsewhere in this Magazine Mr. J. S. Diller has published the results of his petrographic studies of rocks collected by the writer from the island, which show that the older rocks from the base of Pelée and Carbet are hypersthene and horneblende-hypersthene andesites, and the material of the later eruption hornblende-andesite pumice, while the later crater material of Carbet is dacite. Again, much of the material which we now call tuffs exposed in the same places are old mud flows or banks or layers of ashes (lapilli) which have been partially consolidated by the percolating moisture.

There is no evidence in the southern and eastern portions of the island of any volcanic activity within historic times. Omitting from further consideration the older southeastern divisions, the northwestern peninsula alone further concerns the present story.

The Pitons of Carbet and Pelée are the nipples of a pair of twin volcanic mountains which rise from 9,000 to 10,000 feet above their subterranean base. The 4,000 or 5,000 feet of these mountains exposed above the sea are everywhere composed of exactly the same mineral material ejected during their long volcanic history, but varying somewhat in form. At places in the neighborhood of Fort de France and St Pierre up to a height of 2,000 feet some of the rocks are massive crystallines, which undoubtedly were origi-

Photo by Robert T. Hill

The Beach shows the Force of the Return Wave (*page 261*)

nally either erupted as lava or represent the cooled stocks within the necks of former craters which have been exposed by erosion. The greater mass of the material, however, is in the form of volcanic tuffs and conglomerates representing the old crater-thrown débris, in many cases worked over by the streams of the successive eruptions. This is beautifully exposed in the numerous bluffs, from 50 to 200 feet in height, which everywhere mark the truncated line of the northwestern peninsula.

GEOLOGICAL HISTORY

The configuration and sequence of formations indicate the following important events in the history of the island:

1. That it originally consisted of volcanic piles rising from the sea bottom in the area along the eastern shore.

2. That Montagne Carbet and Pelée, constituting the northwestern promontory, are successively newer and later volcanoes, which have grown parasitic to the westward of the older and original volcanic site.

3. That Martinique has been losing in area to the eastward by the planation of the sea and growing to the westward by the successive eruptions of ejecta.

4. The elevated deltas and marine formations bordering the seacoast testify that in addition to the growth of this island by piling up of ejecta it has participated in the epeirogenic movements which marked the history of all the West Indies in late Tertiary and Pleistocene times.

POLITICAL CONDITIONS

Martinique is officially termed a colony of France. While this is true, it is not a colony as the American and English people understand that word. Our ideas of colonies are founded on the English conception, implying dependencies without participation or representation in the legislature of the mother country. To all intents and purposes the island is practically an integral part of France, with elected representatives to the French Senate Chamber, and the people possess as complete autonomy and liberty as the departments of France. In no sense is this government analogous to the colonial system of Great Britain, where the people do not possess citizenship or complete local self-government.

This is not the time or place to discuss colonial government. I only wish to make the point that the people of Martinique are free citizens of a republic which does everything within its power to foster and encourage and increase their prosperity, and leaves to them the fullest exercise of their personal rights and franchise. As a result, the local products and industries are most diversified; the peasantry are permitted to acquire and own places; the government is absolutely republican and democratic, and the people are of a most cheerful and contented disposition.

Photo by Robert T. Hill

Among the Ruins of St Pierre

The English West Indies are blighted and dying from the colonial system of government. In Martinique there are still virility and hope It is true that the island has suffered from the decline in sugar, but, on the other hand, the government has met these conditions by

improved methods of culture and refining, while diverse agriculture is practiced. Such temperate vegetables and fruits as lettuce and strawberries are grown by the Martinique people upon the higher slopes of the mountains, while upon the English islands the people do without these things because they say they cannot be grown. Cologne water, rum, and kid skins of an excellent quality for gloves, and other minor industries add considerable revenue.

It is also true, as the *Royal Mail Guide* stated, that there are no tennis courts or golf links in Martinique; but it has a landscape dotted throughout by homes of a happy peasantry, to say nothing of villas and estates where one can find all the refinement of modern Europe.

Neither is the administration of Martinique so bad as painted. Public improvements abound everywhere, and each commune possesses excellent schools. There are four great public hospitals upon the island and many high institutions of learning. The Lycée at St Pierre had a collegiate faculty which was apparently of excellent standing, and in the destroyed city were astronomic, physical, and meteorological laboratories, such as are found nowhere else in the islands. If the other colonial governments had been as enterprising in this respect, a store of knowledge would have been acquired during the present catastrophe which would at least have paid for the maintenance of such stations. Much attention was also paid to agricultural science in the Lycée at St Pierre, and some of the publications of its professors on this and botanical subjects are the best in existence.

ECONOMIC CONDITIONS

Notwithstanding the statements of Hearn and other writers concerning the decadent conditions in Martinique, from an economic standpoint, in comparison to all the neighboring Windward Islands, it is prosperous and flourishing and far better off in every way.

There were 1,150 sugar plantations on the island, with 19 central usines and 148 rum distilleries. There were also 422 kilometers of track for iron cars. The sugar is of the finest quality of white granulated. Muscovado such as is made in the British islands has long been abandoned. This product is entirely consumed in France.

In 1884 Martinique produced sugar to the value of $4,700,000; in 1898, only $2,732,213, the production of rum having increased from $1,600,000 to $1,800,000.

There were 1,500 hectares in cacao, and the exports were 635 tons, valued at $260,000; 6,000 hectares of coffee, producing 3,334,000 kilos, valued at $1,663,000. Campeahy-wood, vanilla, tobacco, indigo, and ginger were also probably grown.

Martinique imported from the United States horses, mules, salt and smoked meats, butter, oleomargarine, flour, fresh fruits, leaf tobacco, dried vegetables, lumber, coal, glass, vehicles, harness, clocks, sewing-machines, furniture, buckets, bottles, and lamps. Martinique imported cattle from our island possessions, Porto Rico and Vieques.

Above all, there are 10,000 *proprietes vivrieres*, or small peasantry holdings, in Martinique. It is estimated that each of these little properties utilizes three workmen to each cultivated hectare.

These small places yield a variety of culture, but produce little for export, apart from the cacao. A brief glance at one of these permits one to enumerate the principal products. At the side of the house there are trees furnishing fruits in abundance, mangos, avocatas, sapotilles, gayaves, caimites, carossols, star-apples, oranges, mandarines, limes, pamplemousses (a large citron fruit, which we call shaddock), citrons, bread-fruit trees, etc.; then there are many kinds of banana

Photo by Israel C. Russell

Mud-plastered Landscape, South End of Morne d'Orange (*see page 258*)

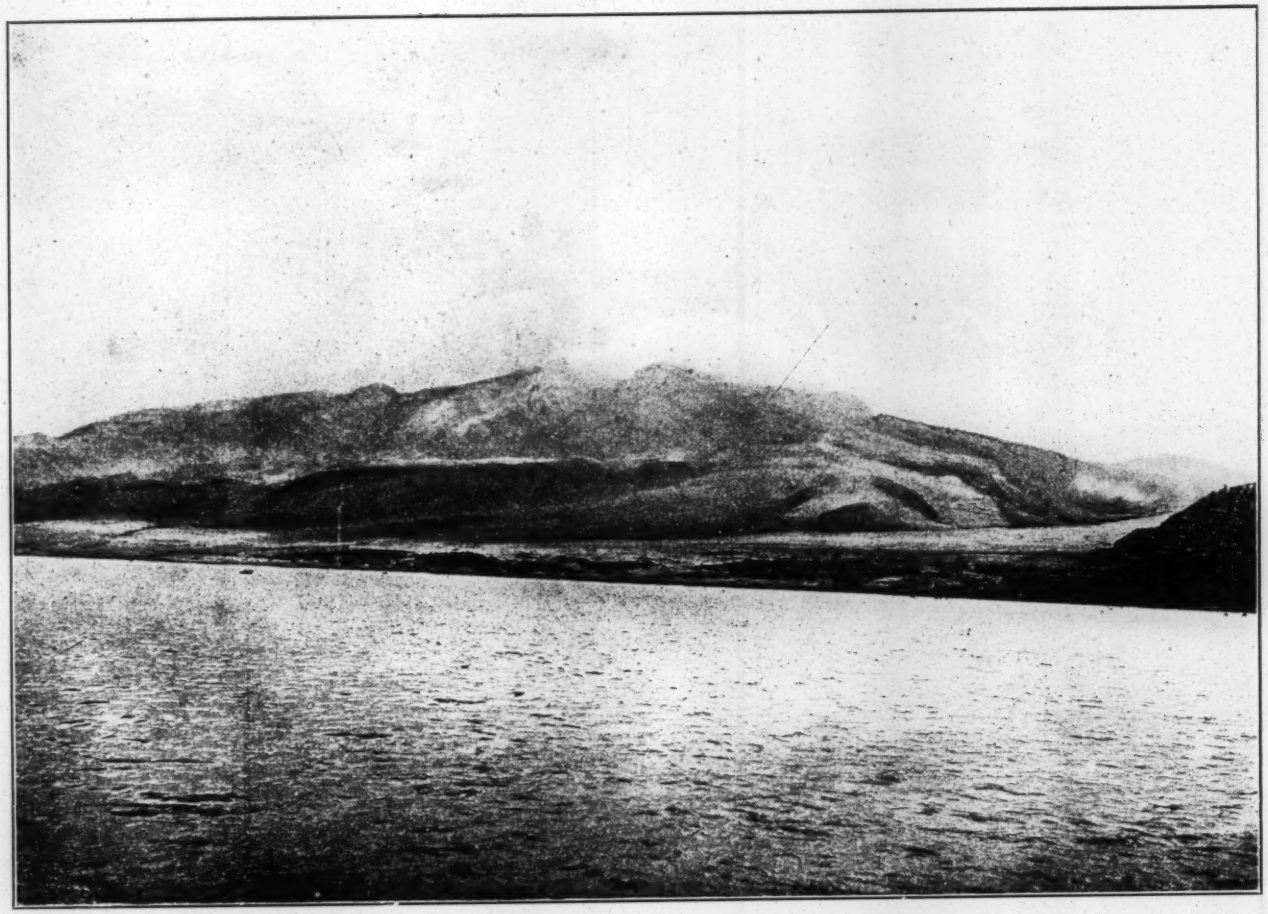


Photo by Israel C. Russell

Montagne Pelée and Destroyed North End of City

"In that triangular space, some 20 miles in area, there was not a thing left alive, not a tree left standing" (*see page 272*)

plants, which produce various kinds of fruit, both of the peculiar species used for cooking purposes and the numerous varieties of fig bananas, which are eaten raw. There are also tuffs of sugar-cane, which is much appreciated as a food ; a few cacao trees, and some Arabian and Liberian coffee trees. Several varieties of spices also grow, and under a tunnel of bamboos one finds christophine, pommes-lianes, and barbadine, while in inclosures are planted vegetables and the Caribbee choux (a kind of root), colocases or Chinese cabbage, manioc, camaioc (the non-poisonous kind), and potatoes of different varieties.

About these small places there are also a few of many kinds of cattle—a small Creole horse to ride, a cow for milk, and a few pigs and some goats. In the southern part of the island one finds sheep. Near the seashore the small houses occupied by fishermen are surrounded by all the utensils necessary for this industry, such as coils of line, nets, and boats lying on the shore.

THE DISASTER

COMING EVENTS CAST THEIR SHADOWS BEFORE

The reader of current events is aware of the general features of the great tragedy which took place upon the 8th of May. This article will point out, so far as can be learned from the reports of today, the essential features of the catastrophe and their interpretation.

The people of Martinique looked upon Montagne Pelée with pride and love. Its charming ravines and forests were the home of myth and legend; the crater lake at its top a pleasure resort. That she would visit her children with calamity, the Creole could not believe.

Once before, in 1851, Pelée had grumbled. In the *Bulletin Official* of 1852, page 3, is recorded a tradition inherited from the Caribs, although without historical foundation, that Montagne Pelée had been the site of an active volcano. This tradition existed from the establishment of the first European settlements in the island and was most strongly impressed upon the people. The conical form of the mountain, similar to that of other volcanic peaks ; the epithet of "Pelée," or "shovelful," given to its summit ; the presence of a lake—all proved the existence of an ancient crater at that point. The pumiceous character of the soil for a radius of many leagues and the contour of the mountain showed the people that Pelée had a secret which they might well fear.

It is also an important fact that in one of the craters of this mountain was a place where sulphur had been found, to which the ominous name of La Soufrière had been given. This soufrière was not the summit lake, as was the case in St Vincent, but its position in one of the gorges to the southwest of the crater was significant.

But there has been more visible evidence that Pelée was a slumbering volcano than volcanic physiography and the above-mentioned Carib tradition left to the French settlers. It is true that Martinique had not had many earthquakes in its history. In 1839 there were some few movements that shook Fort de France. On the 10th of May, 1851, there were earthquakes in Martinique—rather unusual occurrences in the history of the island, although some of its neighbors are quite given to them. On the 5th of August, the same year, St Pierre awakened from its sleep to ascertain that it had a real volcano at its doors. Toward eleven o'clock at night sinister rumblings came from Pelée. When day broke, the people found their houses covered with gray ashes, which gave to the city the aspect of having been visited by a hoar-frost,

and this ash covered all the country between Carbet, Morne Rouge, and Precheur, just as ashes now cover the same district. The Rivière Blanche also flowed a torrent of black or slaty mud, as it now flows.

But soon the rumblings ceased, the ashes turned into fertile soil, the Rivière Blanche once more assumed the color from which it derived its name, and St Pierre forgot the intimation which Pelée had given of the great secret within her heart until about a month before that secret destroyed her.

THE FIRST RUMBLINGS

Just when the present eruption began no one can tell. In the month of May, 1901, a year before the catastrophe, a picnic party to the summit of Pelée discovered a small fume rising from one corner of its ancient crater lake, which smelled of sulphur and killed the foliage of a tree from whose foot it ascended.

Mrs. Prentiss, wife of the American consul, in her letter to her sister, stated that on Wednesday, April 23, she heard three distinct shocks or reports in St Pierre, which were so great that the dishes were thrown from the shelves and the house rocked. These were probably the first effects of the present series of explosions noticed.

On April 25 everybody saw a great cloud of smoke toward Pelée, and from that date until the catastrophe small explosions of smoke and steam occurred. Professor Landes noticed these from April 25 to May 7.

Friday, April 25, Julien Romaine observed a wreath of smoke rising from the summit crater. He went up to investigate, and saw a remarkable black mixture of bituminous appearance bubbling and boiling, rising and puffing. Jets of white vapor and boiling water escaped and then fell back brusquely.

On April 27 another eyewitness from St Pierre discovered, what should have been an alarming fact, that the lower Soufrière or L'Etang sec was in eruption. Looking down upon it from above, he saw a new hole some 26 feet deep and 39 feet wide, in the center of which was a top of molten column shimmering like glass and a muddy-water pool. From the cells of the funnel jets of steam fumed in the air, and ashes were everywhere around. The account was preserved in the *L'Colonie*. From time to time there were showers of ashes and cinders, and from April 28 rumblings were heard in St Pierre.

A gentleman writing to M. de Blowitz, correspondent of the London *Times* at Paris, noted that Pelée had been emitting clouds of smoke for three weeks, but the smoke seemed to be produced so normally that even those who were inclined to look on the dark side seemed not to dread the catastrophe.

From April 29 to May 5 ashes increased steadily, breathing became more uncomfortable, eyes smarted, and throats were sore. On April 29 ominous rumblings of the mountain were heard at St Pierre and whitish smoke was seen rising from the top. On that day fine dust began to sprinkle over the city.

From April 29 to May 5 the streams began to swell; the Roxelane and Des Peres became raging torrents, carrying débris and dead fishes through the city.

April 30 there were three tremblings of the earth, at 3.40, 5.10, and 6.10 a. m. "These were not noted by the people, because they took place horizontally," records the paper. Was there a seismoscope in St Pierre?

On May 2 the first series of eruptions occurred and ashes fell on St Pierre. Work was suspended at the Usine Guerin because of the clouds of ash and cinder. Could these have been from the Soufrière, hardly a mile away?

After this date it was continually noticed that columns of cinders and steam were produced at the exact spot where the new crater was found.

The eruption of May 3 occurred at eight bells, but its effect did not reach Fort de France. It was characterized principally by dense yellow-brown fumes and boiling mud, which ran down the Rivière Blanche.

At 1.05 p. m. the first mud flow came down the Rivière Blanche, which had been of a dark hue for many days. This caused Mr. Guerin, the proprietor of the Usine at this point, to prepare to depart. Mont Pelée also began to throw out dense clouds of smoke. At midnight the same day flames, accompanied with rumbling noises, lighted the sky, causing widespread terror. On this day the first cable broke north of Martinique at an unknown distance from the shore. Then followed the first serious eruption of ashes.

A rain of cinders which began at 7 p. m. prevented the steamer *Topaz* from approaching Precheur.

E. G., in *L'Colonie*, in his graphic account of his ascent to the summit after the first explosion of May 3, says the top of the mountain was all green and the destruction was far less than below. He also noted that a new caldera had formed in the old crater and was boiling up and flowing into the Lake de Palmiste. As it did not fill up the lake, he concluded that it had a subterranean outlet into the Rivière Blanche. On the 4th of May birds died from asphyxiation from ashes, and this river became a torrent of mud and pumice, large quantities of which began to flow, causing much alarm as to what the night would bring forth. Hot ashes also covered the whole city quarter of St Pierre an inch thick, and while falling made Mont Pelée invisible.

Monday, May 5, at 5 a. m., the eruption of Pelée seemed ended and a calmer state prevailed, although cinders con-

Photo by Israel C. Russell

Mud-coated Surface and Injured Trees, Morne d'Orange (*see page 259*)

tinued to fall on Precheur. At noon a stream of liquid volcanic matter flowed down the mountain side and reached the sea, five miles away, in three minutes. In its rush the flood swept from its path plantations, buildings, factories, cattle, and human beings over a breadth of about half a mile along the Rivière Blanche.

At the mouth of the Rivière Blanche stood the large Guerin sugar factory, one of the finest on the island. It was completely entombed in the mud. The tall chimney alone remained visible. One hundred and fifty persons, it is estimated, perished there, including the owner's son, but the officials give a smaller number.

A remarkable phenomenon occurred after the rush of the mud to the sea. At the mouth of the Rivière Blanche the sea receded at 12.25 p. m., all along the west coast, for a distance of about 100 yards, and returned with gentle strength, covering the whole sea front of St Pierre and reaching the first houses on the Place Bertin. This created a general panic, and the terror-stricken people fled to the hills, though the sea retired again without any great damage.

Terrible detonations were heard hundreds of miles northward, at short intervals, and continued at night. The electric lights failed, but the town was lighted by the flashes of flame from the mountain. Terror-stricken inhabitants rushed for the hills screaming and wailing.

At 7.45 p. m. the cable from Fort de France broke to the north. The end of this cable was later picked up 10 miles due west of St Pierre in 2,500 meters of water.

Professor Landes, who published an interview in *L'Colonie* of May 7, noted that Rivière Blanche at this time was furnishing five times the volume of the greatest power and carrying rocks weighing perhaps fifty tons. This was before May 5.

The *Topaz* refugees stated that on May 5 terrible detonations broke from the mountain at short and irregular intervals, accompanied by dense smoke and lurid flashes. This was awful in daylight, but when darkness fell it was still more terrible.

The awful phenomena of May 5 were so terrifying that people in their night clothes, carrying children, and lighted by any sort of lamp or candle they had caught up in their haste, ran out into the dark streets wailing and screaming and running aimlessly about the town. The mental strain became unbearable, and the *Topaz* was got ready at 3 a. m., and the refugees hurriedly got on board and started at 5 a. m. for St Lucia, where they arrived at 11 o'clock on the morning of the 6th.

On May 6 Pelée was apparently in full eruption. Its detonations were heard in Guadeloupe for two or three hours, and thick clouds overshadowed the summit of Pelée. Fond de Core was abandoned and cinders fell in abundance on Macouba. Five centimeters of cinders had fallen in Precheur, a foot of cinders was reported in the center of the mountain, and three-tenths of a millimeter of cinders fell on St Pierre on that night. People were departing from St Pierre on foot to neighboring villages and by steamer to Fort de France. Country places were being abandoned for lack of water, cattle were dying, and trees breaking under cinder weight. On the afternoon of the 6th, a little before 5 p. m., telegraphic communication between Martinique, St Vincent, and St Lucia was interrupted. There were six cables leading into Martinique, all of which were eventually broken.

May 7, the day before the end, was one of horror in St Pierre, but the volcanic phenomena were not so vivid as before. Detonations like artillery were heard from 10.30 a. m. to 5 p. m. All that day the *Roraima* at Dominica and people of neighboring islands heard detonations. These even reached as far

north as St Thomas. Similar detonations were heard in Barbados, but these may have been from St. Vincent, where the great eruption took place on this day.

On this morning a great crevasse was noticed at the base of Morne La Croix, on the side toward L'Etang sec. This was 100 meters long and 40 wide, and it was feared might undermine the mountain.

In the morning the cable operator at St Lucia received a message from the operator at St Pierre saying, "Red hot stones falling here; don't know how long I can hold out." At 2 p. m. Consul Ayme at Guadeloupe sent a message to the cable office and was informed that all cables north and south were broken. All the cables that went to Martinique were broken on the 7th.

Wednesday night, the 7th, the detonations ceased and fine ashes fell over St Pierre like rain.

The French Governor, M. Mouttet, who was at Fort de France, tried to stop the panic which the volcanic disturbance caused. He declared the danger would not increase, and sent a detachment of soldiers to prevent an exodus of officials, and later went himself with his wife to St Pierre, where they were destroyed.

THE CATASTROPHE

At 6.30, May 8, the *Roraima*, then approaching St Pierre and her fate, reported ashes falling, although the day was fair and the sun bright and clear. It may also be of interest to note that at 7.50 on the morning of May 8 there was to be a new moon in St Pierre.

The rays of the rising sun had hardly descended over the mountain back of St Pierre on the morning of the 8th when, at 7.50 o'clock local time, a great volcanic cloud erupted and destroyed the city and its 30,000 people, seventeen ships in the anchorage, and all the country places between the cliffs of the Roxelane and the Rivière Blanche. The phenomena of this eruption, so far as I have been able to ascertain them, were as follows:

The Witnesses.—Witnesses of this terrible event were many, but of survivors there are few. Of these I personally interviewed Captain Freeman, of the *Roddam*, and Engineers Evans and Morris, of the *Roraima*, who witnessed the event from the sea side, and Mr Ferdinand Clerc and a dozen others who observed it from the land side. I have also carefully analyzed the printed reports of other witnesses.

Some of the witnesses of the eruptions could see only a portion of the phenomena. Father Alte Roché, at Mont Verte, whose story is the most intelligible of those from the land side, could see the summit, but intervening ridges obscured his view of the lower vent and St Pierre. This also was the case with M. Levenaire, who lived northeast of Morne Rouge. The witnesses from the ships could see the sequence of eruptions; but as the edge of the dense black aërial mass of ashes approached them the cloud itself cut off their observation of those things taking place over the city which could be seen by observers from the land side. All of the witnesses, many of them frightfully injured, were too busily engaged in securing their own safety to devote their attention to the phenomena exclusively. Two have given unusually intelligible and accurate accounts of what they witnessed. These are Father Alte Roché, of Mont Verte, and Second Engineer Chas. Evans, of the *Roraima*. I was associated with the latter for a week upon our return on the *Dixie*. The story of Father Alte Roché was given by Mr Skinner in the New York *Times*. Many other witnesses have noted important single facts.

South Photo by Israel C. Russell North

Statue of Our Lady of the Watch, Morne d'Orange, South End of City

This statue, weighing several tons, was hurled 50 feet by the terrific blast (*see page 273*)

Preliminary Air Movement. — Mr Ferdinand Clerc, the chief planter of the island, whose miraculous escape from the city at 7 o'clock on the morning of the 8th has been recorded, informed me that the needle of a large aneroid barometer hanging in his house fluctuated violently, and this fact determined him to leave the city. These fluctuations were undoubtedly disturbances in the air from explosions within the open crater.

Detonations.—Professor Arnoux, astronomer of the St Pierre observatory, at the time of the catastrophe was on the overlooking plateau of Mont Parnaise. He had distinctly heard detonations when the eruption took place.

Jean Marie Evans, a foreman of the Raibaud estate, two miles southeast from St Pierre, in a deep valley, also told me that there were frightful detonations in the mountain just preceding the eruption.

The Eruption.—All witnesses agree that St Pierre was overwhelmed by a cloud of aërial volcanic ejecta, which traveled with great rapidity across from the mountain over the city.

It may be noted here that in all of the many subsequent eruptions which I personally witnessed, those from the summit, especially when black in color and of dense lapilli (ash clouds), boiled out in great balloon or mushroom-shaped clouds, with numerous rolling convolutions, usually dissipating above, but sometimes floating away in great horizontal ribbons. Those from the lower vent were wide columns of brownish smoke, without convolutions, and traveled along the ground surface to the sea.

A Sequence of Eruptions.—According to Charles Evans, the second engineer of the *Roraima*, who with another engineer (killed) was looking at the mountain from the deck, there were three eruptions: First, there was a big puff of smoke from the top of the mountain, not accompanied by noise, which mushroomed and spread out. Then, after a noticeable interval, there was a second and larger eruption (the destructive one) *which did not come from the top of the mountain, but from the side*, and which did not ascend, but rushed down toward him and the city in two great horizontal puffs. On seeing this, the fatal eruption, Mr Evans ran down to the engine-room from the deck. Returning on deck, burned and suffering, he saw a third and irrelevant eruption, which took place in about five minutes after the second one. Evans is positive that the second blast destroyed the town. Camille Houly, at Belle Oncle,

Photo by Israel C. Russell

Guns of Battery on Morne d'Orange Dismounted by the Blast (*see page 273*)

a suburb, also saw the mountain "apparently open over an area of 100 to 200 meters *at a point fully 1,000 meters below the summit.*"

Father Alte Roché, from the high position of Monte Verte, 3½ kilometers south of St Pierre, had a clear view of the mountain, but not of the city or lower vent. He saw a dense column shoot up from the summit of the crater like a column of smoke and steam, which "spread out like the leaves of a palm tree."

Jean Marie Evans, in a valley of the Raibaud estate, one mile southeast of St Pierre, saw the cloud coming out of the top of the mountain, and ran. He said the cloud did not go up in the air like smoke. "It went high, but not like smoke," meaning that it was like a ball or cauliflower, instead of columns.

Mademoiselle Lavenaire, from her father's estate, Beauvalon, 3½ miles northeast of Morne Rouge, and 1½ miles from the crater, saw a column of black smoke issue from the summit of the crater, which did not rise, but settled down toward St Pierre.

Composition of the Cloud.—Its visible composition was of a dense mass of hot ash-like lapilli (ash), which everywhere filled the air. Besides this, gases and superheated steam were apparently present, as will be shown. A ton of ashes was found in the officers' mess on the *Roraima*. From 50 to 100 tons fell upon the deck of the *Roddam*; less than a foot of ashes fell in all the eruptions on the streets of St Pierre. These were piled highest against the north wall.

Density.—The cloud, as seen approaching from the sea, was dense, opaque, and of a brownish black color. Its density was so great as to cause total darkness of positions it enveloped.

Weight.—The cloud was heavier than the air. It traveled along the surface of the earth's configuration instead of ascending. Owing to this heaviness, houses, estates, trees, and people on the higher cliffs above St Pierre were spared, as well as the trees on the southwestern slope of the high summit of area of Pelée.

Motion.—The cloud advanced horizontically through the air, following the configuration at the minimum rate of a mile a minute. Besides the progressive motion, its convolutions surged and rolled. No witnesses could testify positively to a revolving (cyclonic) motion. Some say that it rolled vertically. The priest at Precheur stated that trees fell circularly, but all the fallen trees at that place lie in one direction.

Direction.—The path of the cloud was from east of north to west of south. The area of its destruction is elsewhere discussed. An interesting fact told by Engineer Evans is that "the cloud came against the wind." I cannot interpret this phenomenon. Was there a tremendous indraft?

Heat.—The cloud was hot. All witnesses spared testified to feeling its heat even when beyond its margin. The ashes were hot for hours on the *Roddam*, and still warm when dug into by me thirteen days after the eruption. The lapilli falling upon the *Roraima* were sufficiently hot to cause ignition of rope and bedding, but not to ignite woodwork or the pitch-pine timber on its forward deck.

Mlle. Lavenaire, 7½ miles northeast of St Pierre, to the east of the amphitheater, felt a blast of hot air. Others on the margin of the disaster testify to the hot air. The writer has personally felt the hot blasts of air from subsequent eruptions.

Steam.—In addition to the hot lapilli, there was an invisibie heated substance in the cloud which penetrated clothing without firing it and burned the human skin beneath, as attested by the burns upon the back of Engineer Morris, the breast of Nurse Clara, and others. It is possible that this was superheated steam.

Lack of Incandescence.—There is no testimony that the destructive cloud or its lapilli were incandescent. All parties who witnessed the cloud from the front (advance) testify that they saw no flame or incandescence in it. There is positive evidence that the cloud, in one place at least, was not incandescent. Engineer Evans, of the *Roraima*, who looked up through a skylight as out of a well, says he saw no fire or light in the dense cloud above him. His point of view was the outer side of the destructive circle.

Photo by Robert T. Hill

A Flash of Lightning in Clouds Erupted from Pelée

Flame.—There is much evidence that flame developed in the cloud after its eruption. All persons who witnessed the cloud from the rear or land side testify to seeing great sheets of flame or fire develop within the cloud, suggestive of sudden ignition. Priest Des Prez, of Precheur, saw red fire in the air following after other phenomena observed by him. "In the city behind the smoke came a sheet of flame," said Mr Le Clerc. Victor, a native, whom I met at Deux Choux, six miles from St Pierre, and who saw the eruption from a neighboring estate, stated that at the time of the explosion for a moment he saw the heavens clouded with flame; five minutes afterward total darkness.

Professor Arnoux says that after the cloud had settled over the city there was a flash of flame and he put his hand over his face to shut out the awful sight.

Father Alte Roché states that after having seen the summit cloud roll out, after having run from it 200 yards, and after having fallen down, as he got up he saw a blinding flash over the city. He said: "As I looked there was a blinding flash of fire, and in a moment the whole beautiful city was in flames. The flame seemed to travel like lightning over the city from north to south; but it was not lightning. It looked as if the black cloud from the mountain had been ignited as soon as it reached the city."

Mlle. Lavenaire, 7½ miles northeast of St Pierre and out of sight of town, saw a flash of flame within two minutes after the summit cloud had erupted.

Many testify that while the cloud was not visibly afire at the time of its eruption it inflamed objects in its path over the city. Evans said that wherever the cloud touched the houses in town they took fire. As the houses were of stone, with tin or tile roofing, containing but little combustible material, the temperature must have been intense to cause such sudden inflammation.

Lightning.—Tremendous displays of bolts and flashes were seen at St Vincent and Pelée within the clouds ejected from the volcano during eruptions. The evidence of lightning around the erupted summit clouds after they had left the crater is indisputably testified by many witnesses. I have personally witnessed the phenomena in subsequent eruptions.

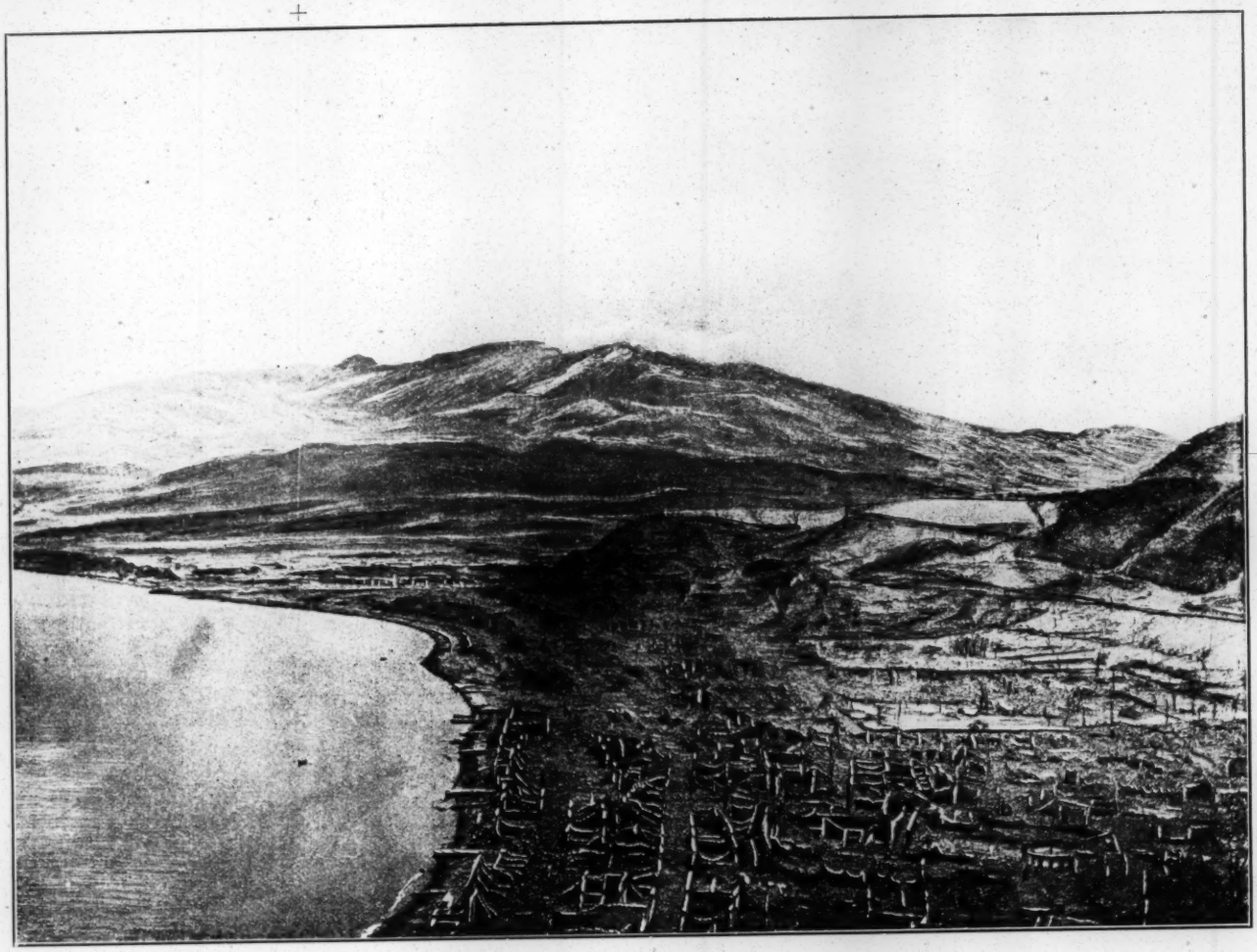


Photo by Israel C. Russell

"At my feet lay the dead city, silent and gray" (*see page 272*)

Showing summit of Pelée; standing walls south end of city; north end of city extended along coast to extreme left of picture. Lower vent, as located by Mr Hill, is behind the lower hill below the cross (+) in upper left-hand corner of picture

G. Mazot, in *L'Colonie* of May 5, stated, in describing the current eruptions, that "flashes of lightning in culminating zigzags moved the length of the mountain. This phenomena is produced during the night with a beautiful horror. The sparks shoot along the summit in every direction." Foreman Jean Marie Evans distinctly and voluntarily testified to me that there was much lightning on the St Pierre side during the eruption. Father Alte Roché saw lightning playing incessantly through the summit cloud preceding the catastrophe.

Scarcity of Visible Effects of Lightning Strokes.—There is no positive evidence of death or destruction from lightning, nor is there sufficient data to say that there were no such effects. No fulgurites were found, no splintered trees, no shattering. The ironwork was bent by combustion heat of the burning city. I saw hundreds of commercial bars of iron standing against the walls of a shop, which were unfused and unhurt. No fusion whatever of metals was observed. The only apparent electrical phenomenon reported is the allegation that Mr Clerc found that the iron cross which formerly surmounted Morne La Croix had been melted down to its stone pedestal.*

M. de Blowitz says that the telegraph office and its contents were burned, and that some fragments of the apparatus were thrown a hundred yards. The office might have been burned by electricity, but the throwing was not due to this cause.

The correspondent of the *Sun* of May 13 says that the bodies looked as though they had been struck by lightning; but this is not proven.

Important electric studies are being made by officials of the French fleet in the vicinity. It is an interesting coincidence that the marconigraphs on *L'Tage* were made useless during subsequent eruptions.

Magnetic Storm Probably Accompanied Phenomena.—Mr Otto H. Tittmann, Superintendent of the U. S. Coast and Geodetic Survey, reports that the delicately suspended magnetic needles at the two Coast and Geodetic Survey magnetic observatories—the one situated at Cheltenham, Md., 16 miles southeast of Washington, and the other at Baldwin, Kans., 17 miles south of Lawrence—were disturbed, beginning at about the time the catastrophe at St Pierre is reported to have occurred. The wave of fire struck St Pierre and a clock was stopped at 7.50. The magnetic disturbance began at the Cheltenham Observatory at a time corresponding to 7.53, St Pierre local mean time, and at the Baldwin Observatory 7.55, St Pierre time. This disturbance was also registered in Paris and in the Hawaiian Islands.

Evidence of Gaseous Substances within the Cloud.—There is no direct oral testimony of gas within the cloud, as the people who witnessed it were not students of gaseous phenomena. All silverware in the ruins was blackened, notably the bucket of plate rescued from Consul Prentiss' house by Consul Louis H. Ayme, which resembled old black junk. A silver platter picked up by an officer of the *Dixie* was black and corrugated. A bronze, silver, and gold image picked up by another officer was likewise blackened. In fact, every metal relic susceptible to sulphur discoloration showed its blackening effect. Twigs from the trees collected by me and analyzed by Dr Steiger, of the Geological Survey, showed a sulphurous coating.

The presence of sulphur gases may be reasonably inferred. The soufrières and most of the hot waters of the Caribbee craters are sulphurous and evict

*The World's Work for July, received since the foregoing was written, states that Professor Heilprin has found evidences of lightning strokes on objects in the city.

sulphureted hydrogen gases. Nearly all the old calderas contain native sulphur. The soufrière of Pelée receives its name from the sulphur found there. Parties who visited the summit a few days before the catastrophe, as recorded in *L'Colonie*, exposed silver and it was blackened. They noted black powder, resembling plumbago, covered trees near the crater; that the water of the lake contained great quantities of sulphureted hydrogen, and that when the water was put in bottles the gases forced out the corks.

The deputy mayor, Labat, told me that the captain of the *Suchet* picked up pieces of pure sulphur in the ruined streets of St Pierre on the afternoon of the catastrophe. A newspaper man describes splotches of flame on the ships, which might have been sulphur.

The city of St Pierre was filled with sulphureted smells for days before the eruption, as testified by the following extract from a letter by Mrs Prentiss, written and mailed a few days before her untimely death: "The smell of sulphur is so strong that horses on the street stop and snort, and some of them drop in their harness and die from suffocation. Many of the people are obliged to wear wet handkerchiefs to protect them from the strong fumes of sulphur."

A survivor named McDonald, who arrived in Norfolk, Virginia, on May 16, claims to have escaped from St Pierre to a ship in a rowboat, and that he was picked up by the *Suchet*. He said the air was filled with mud and lava, and the sulphur fumes were so strong that breathing was difficult.

Deputy Mayor Labat said that when he approached St Pierre on the evening of the explosion there was a terrific odor of sulphur in the air. I myself have smelled sulphur fumes in the air from later eruptions.

Foreman Evans said there was a little sulphur smell, but the smell was like something dry, like steam with a little sulphur.

Evidence of Steam.—Steam clouds were seen by Father Alte Roché, rising from the erupted clouds. Steam may be inferred, as it was present in all the eruptions subsequently seen. The burning of persons' bodies through their clothing without firing the clothing indicates the presence of steam, and the great rain of wet mud which followed the catastrophe from a cloudless sky, might theoretically be assigned to the condensation of steam ejected from the volcano.

Force.—A tremendous destructional force was apparent. It uprooted trees, destroyed buildings, threw people and objects, made the sea recede, overturned ships and destroyed their rigging. It is impossible to conceive that this force was initial from the volcanic vents, two and a half and five miles distant.

The Force Aërial, not Terrestrial.—Tops of walls were thrown down, foundations standing; pedestal standing, statue blown off; rigging and upper works blown off ships, hulls keeled over. The stones on which the light-house stood were torn asunder and thrown great distances. The statue of the Virgin, as observed by Professor Russell on the lower cliff near the south end of the city, was thrown to the south, with her head lying to the north. Many of the trees in the south edge of the town were thrown south against the cliff, although others in the town were sufficiently rooted to withstand the forces. Against the cliff in the southern part of the town are hundreds of tin roofs. On the cliff line above the town many trees are still standing with their branches and scorched foliage, and a red-roofed villa preserved there, with furniture and foliage intact, shows that the lines of fire did not reach there. Mr. Prudhomme, on the bark *Teresa lo Vico*, was thrown on deck, his wife on top of him.

The shock was felt as far as the village of Deux Choux, eight kilometers to the east, and Mont Vert, six kilometers south, where Father Alte Roché was thrown down.

According to Engineer Evans, there was a great horizontal disturbance of the water, caused by the aërial force. This struck the port quarter of the *Roraima*, her head being on shore. She keeled to the starboard, so that the bridge got under water and water came into the hold through the fiddlers. The wave lifted the *Roddam* so that her anchor chain broke, and she was enabled to escape. It also took James Taylor, of the *Roraima*, out to sea, and its return movement brought him back to a buoy, from which he was rescued. This return wave bit little triangular pieces out of the beach.

The direction of the force was radial apparently from a center. In the south end of the city objects were blown southward by force from the north, the north and south ends of buildings blown in. The *Roraima*, at buoy, was struck by force from north; the *Grappler*, at mouth of the Rivière Pères, off the north edge of the city, was destroyed by force from the east; trees in the vicinity of the Rivière Mare were blown by force from the southeast; bamboo and foliage slopes of the eastern cliff toward Morne Rouge were bent by force from the west, the Jardin des Plantes destroyed by force from west of north.

The Center of Force.—This seems to have been near the north end of the city where destruction was greatest, the effects decreasing radially in all directions. Among the evidences of force are the fact that in the northern part of St Pierre the buildings were absolutely pulverized. Not a vestige was left of the little village of Fond Core, north of the city. It is said that not a piece could be found of the great rum factory, with its heavy iron machinery and castings.

Return Force.—A return force is evidenced by the south end of buildings blown northward and by the testimony of witnesses. Father Alte Roché, three miles south, who was knocked down and gasping for air, says "a breeze sprung up from the south and revived me." Engineer Evans says that the force had the strength of a hurricane, and noted that it went out and came back. All who felt it testified that they were pushed down by the air. No evidence of vertical earthquake or fissuring was noticed or is recorded in the phenomena of the surrounding country. The buildings, bridges, and earth embankments within a mile of the zone of disaster show no disturbance. People similarly located testify that there was no earthquake. Is there any other explanation of this force than explosion?

Exhaustion of Air.—Many witnesses on the perimeter of disaster testified that they were not suffocated by ashes or detectable gases, "but could get no air to breathe." This language, or words to its effect, is the testimony of every witness, from the intelligent ship officers to the humble negro or peasant. Engineer Evans stated that he could get no air to breathe on deck after the explosion until he got below.

Foreman Evans, of Raibaud estate, said: "It was not hard to breathe until all was nearly over; then we felt as if we could get no air."

Noises.—Evans insisted that there was no noise at all when St Pierre was destroyed, other than a deafening roar. Some describe hissing noises like roaring silk. I have heard no evidence of a resounding explosion, but the testimony concerning noises was not thoroughly inquired for.

Conflagration.—All witnesses testify to the sudden and instantaneous conflagration of the city. Father Alte Roché noticed that it swept rapidly from north to south. In parts of the city all combustible material was destroyed, but in the center and southern parts many

trees stand which were only singed of their leaves and twigs.

Duration.—The whole catastrophe, from beginning to end, was over in less than three minutes, although the ruins are still burning.

Succeeding Rain of Mud and Pumice.—Immediately following the destruction there was a rain of mud, or, as a negro witness stated, wet met the ashes in the sky, turned to mud, and it fell to the ground. This mud plastered all objects upon which it fell as with a thick coating of cement—houses, ships, and heads of human beings. The landscape was everywhere coated with an envelope of this warm liquid from the sky. This rain of mud continued for one-half hour after the explosion. The rain of mud is strongly suggestive of the condensation of the volcanic steam of the eruption in the air as a source of the moisture. H_2S, ignited, moisture from the combination of the H_2 with the O, may have theoretically also resulted.

Accompanying the rain of mud was a shower of pumice-stone. These stones were undoubtedly those which had been thrown higher into the air from the explosions than the other ejecta, and which with a long trajectory came down last. These stones or those of the eruptions, falling on the soft plastering of the landscape, rolled down the hillsides, striping the plaster with their parallel paths as if it had been raked with a coarse comb.

Death.—Death was an accompaniment of any of the phenomena of the eruption described, and undoubtedly occurred in many ways and in different degrees of suddenness. Many were killed by inhaling hot lapilli, notably on the *Roraima;* others burned by same on the *Roddam;* others burned by steam; others killed by force; others singed by flame. All did not die instantly.

Nearly all burns of the wounded survivors from the ship, according to Dr Riley, were of the first degree, affecting only the epidermis. There were also some burns of the true skin. The eyes of the wounded were unaffected and the eyelashes intact; on the other hand, remains on shore were horribly burned to the quick.

Officer Scott, of the *Roraima*, tells of children who moaned for water, "unable to swallow because of ashes which clogged their throats." "One rinsed out his mouth, but could not swallow on account of ashes which burned his throat."

It is not true that all the inhabitants died from asphyxiation in the position in which the cataclysm surprised them. Many were found in positions indicating flight and search of shelter. The captain of the *Roddam* told me he saw people running about the water edge for several minutes. In St Vincent it is said that a man was found dead in the act of twirling his mustache; another with his hand holding his pipe. An eyewitness told me that he saw in St Pierre a man holding a struggling, frightened horse, both dead in this posture. The man running the donkey on the *Roraima* was killed instantly where he was sitting; he never moved. Another person, a foreman, was standing by, holding the handle of the pump, when killed; and yet near by a child and nurse were only burned, and recovered. It is also stated a man who died on the *Roddam* was burned internally.

EXTENT AND PHENOMENA OF DEVASTATION

The effect of the preceding eruptions of May 3 and 5, and of the eruptions which have taken place since the day of the great catastrophe, notably that of May 20, all of which occurred within the same general district, are so intermingled that it is difficult to distinguish them.

The Area of Devastation as seen by me between May 20 and 30 represents the effect of all of these eruptions. As a whole, this area includes all the country between Carbet and Precheur bounded by the north and south cliff lines previously mentioned in the description of the configuration as constituting the amphitheater of death. This area practically includes the country between the Rivière Mouillage on the south and the Rivière Blanche on the north, with the addition of two coastal prolongations seaward of the cliff lines, which bend southward of the Mouillage toward Carbet and northward of the Blanche toward Precheur.

The Mud-plastered Landscape.—The whole of this area, both the included valley and the faces and summit edges of the escarpment, is enveloped in a smooth compact casing of mud plaster, resembling a coat of cement, which is striped by parallel erosion scratches which have scored the surface. This cement covers a well-defined zone, representing the area of the catastrophe, the shower of mud following the ignition cloud. It may be noted that pouzzioloni, a natural cement, made from volcanic material, was about the only economic product of Martinique's geological formations, and was extensively found around St Pierre.

Between the mud rivers south of Precheur and the Rivière Mare the coast line bluffs. Along this bluff extends the remains of what was once a magnificent and costly highway. Its macadamized surface is now covered to a depth of three feet with mud, and obstructed here and there by fallen trees. In the mud there are numerous bodies of animals, cattle, horses, and donkeys, with occasional human remains.

Destruction of Habitations.—All the homes of the 25,000 people of St Pierre are destroyed. Outside of St Pierre, in the area below the cliff line, there is not a visible sign remaining of one of the homes of the 15,000 people who inhabited them. Annihilation is the only descriptive term. While remnants of houses remain in St Pierre, the annihilation extends northward to one-half mile of Precheur.

Among the country places destroyed around St Pierre, according to M. Houly, were the following: Perinelle, Pecoul, Reduis, La Trois Points, Jardine des Plants, the Bishop's house, L'Habitation, Trouvallon, Miron, Tricolore, Lance, La Touche.

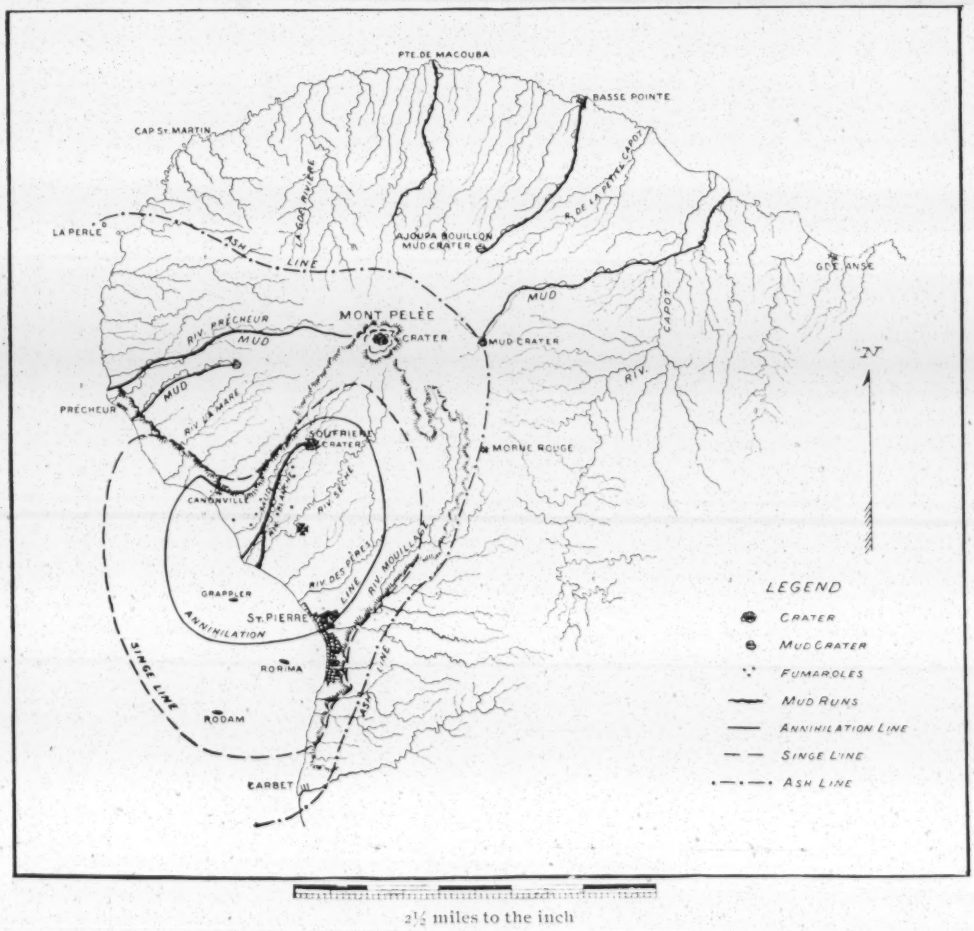
Denudation of Vegetation.—Over this entire area the vegetation is entirely denuded, with the exception of a few larger trees standing in St Pierre, from the Mouillage southward, stripped of all leaves and twigs and bark, only the trunks and larger limbs remaining. On the edge of the cliff above St Pierre, several large trees with foliage singed remain standing in the area of mud.

In the gradients of the deep valleys of the headwater ravines nearest the summit, on the St Pierre slope, trees of the *grandes bois* still stand with foliage untouched. In protected lateral ravines of the south cliff, near the Jardin Botanique, bamboo and other vegetation was still green, while killed on exposed hillsides above them.

The vegetation on the summit of the south cliff to an altitude of 100 meters was killed; in the deep valleys of the stream entering the sea at the south end of St Pierre, cane and grass were not affected.

Along the coast benches vegetation was blasted as far south as the northern edge of Carbet village. In the south edge cane and palms are green. To the north the coast cliff as far as the first stream, one-half mile south of St Pierre, is also denuded and blasted to an altitude of 200 feet or more. Nearer Precheur dead trees and palms are broken down three or four feet from the ground and lie to the westward.

Ash (Lapilli-covered) Zone. — The whole of the island has received a



Map Prepared by Robert T. Hill Showing Zones of Devastation in Martinique

sprinkling of lapilli from the aggregate eruptions. This is not conspicuous or discoloring, however, except within an area a mile or two beyond the mud-coated area and over the latter. The quantity and extent of ashes erupted cannot be estimated, nor is it material at present to do so.

Mud Rivers in the Devastated Plain.—The Rivières des Peres, at the northern limit of the city, and the Seche, within the amphitheater, have been the sites of mud torrents from the eruptions.

The coastal extension of these stream-ways is so filled with mud that their former valleys are filled up level with the low divides, so that they are practically obliterated. What was the lower valley of the Rivière Blanche for a mile back from the sea is so filled up that now it is a convex elevation near the sea, built up by successive mud flows, so that streams of the latter run down from it into the Seche.

The Rivière Blanche is still flowing mud in intermittent gulps from the

lower crater of L'Etang Sec. To the northward there are conspicuous mud streams near Precheur, presumably from the hot springs above that town, but it is not proven. Other mud rivers outside the area of devastation are elsewhere mentioned.

One mile south of Precheur there were two small canyons, in the bottom of which were two flowing streams of viscous liquid mud coming down with sluggish movement, choking out the small narrows within the banks and then suddenly starting forward again with a horrible gulping noise. In this mud were many small pieces of pumice.

Beside the mud delta forming the level at the mouth of the Rivière Blanche, there are many great boulders of pumice on the adjacent level, brought down by the preliminary eruptions of water. The old mouth of the Rivière Seche is filled with these bluffs.

New-built Land from Sedimentation.—Off the mouth of the Rivière Blanche the sea border is extending from the deposited mud. A small islet, 50 feet long, 10 feet from the shore, has appeared above the water to the north of the mouth of the Blanche, composed of sedimented mud and fumarole deposits.

Wave-cut Bights.—From St Pierre to Precheur there are many small triangular bights in the beach and enlargements of the mouths of streams cut by the force of the return wave.

The mouth of the Rivière Mare has been deeply incised and presents vertical new cut bluffs, some 20 feet in depth, which render the crossing of it impossible.

The movements producing these bights consisted of an outer motion of the water from the shore and a return wave. They were caused by explosion within the air and not by any movement of the bottom of the sea. The waves were observed at Fort de France.

It was reported from St Lucia that there was a strange commotion in the sea, as if the waters were boiling over a large area, as located with a range-finder from Castres, on the 7th and 8th, as if two waves had met. This report lacks verification.

Changes in the Summit.—It is rumored that toward the north the crater rim has broken down, and that Morne La Croix of the southwest rim has gone. Admiral Servan informed me that several officers had measured the altitude of Pelée and had found that it had lowered 60 meters by the destructive explosions. The Lake of the Palmistes is gone, while in the old bowl of the crater, through the great gap in its western side (which was there in 1823), may be seen a great pile of pumice, over 100 feet in height.

New Geological Formations Made.—With the exception of the new addition to its soil of layers of mud and ashes, the filling in of the lower streamways of the rivières of the amphitheater of disaster, and on the east and north side the fringing load of sediment along their mouths, and the new pile of pumice around the summit vent—new formations added to the mother pile—no other positive topographic changes have taken place in Martinique.

Topography Unaltered.—Otherwise the configuration of Martinique today shows no serious change. Every hill, valley, scarp, precipice, or other surface feature of the relief as laid down upon the map of 1823 is distinctly recognizable. The changes are merely the superficial destruction of vegetation and the veneering of a small triangular area with a thin layer of ashes and mud, so that it is converted from a green carpet of cane and wood land to a barren, desert mountain landscape like that of Arizona.

Small Proportion of Island Affected.—Nineteen-twentieths of the area of Martinique is as green and beautiful today as it ever was.

Of the total area of Martinique, about 380 square miles, only 12.5 square miles

have been seriously affected by the eruption. This area principally embraces a triangle between Carbet, Pelée Peak, and Precheur village.

No Lava Flows.—There have been no lava flows whatsoever, nor, owing to the mineralogical character of the rocks, would these hardly have been probable. The solid ejecta from the mountain have consisted of lapilli and blocks of pumice, together with some of the old crater material of previous eruptions. No true bombs have been ejected, nor molten rock in any form. Incandescent stone or pumice has been blown from its top at times and fell in showers immediately around the crest, as was witnessed by Mr Morse, of the *Herald*, and the writer, on May 25; but this quickly cools upon reaching the air, and cannot be called lava.

No Subsidence or Uplift of Land or Sea Bottom.—There has been no subsidence or elevation of the land that can be recorded, nor of the adjacent sea bottom. The little rock of La Perle, a half mile off the north coast, stands there today as it did when I first saw it, five years ago; the unmistakable benchmark of elevation or subsidence—the horizontal groove cut by the surf line in the base of the cliffs—is everywhere as it was, sprawled over by the same spray-living mollusca and beds of algæ.

The only change in the littoral are the vicious little bites into the banks and the mouths of the rivers made by the return wave at the time of the great eruption.

No Fissuring Earthquakes.—Neither have there been any serious or positively proven earthquakes resulting from the rending of the earth along fissures. Within a mile of St Pierre the bridges, roads, houses, and trees stand unshaken. Eyewitnesses testify that they felt no quaking, only a force in the air which tended to knock them over. On the other hand, there have been jars and tremors from the tremendous explosions within the mountain, and these were of sufficient force to break the cables.

Measured by the geological standard, only a new formation has been made by a passing event in nature's workshop.

Has nothing happened? Ask the 30,000 mouldering dead, the sixth of Martinique's population, which moulder beneath the ashes of St Pierre.

THE VOLCANO

In describing the effects and phenomena of the eruptions, I have almost forgotten the Hamlet of my story—the volcano which has caused the trouble. Across the weird landscape from the summit of Pelée the volcano still sends forth its occasional bursts of steam and cloud, rising in great mushroom clouds to 15,000 feet above the sea. At night these are vivid with lightning flashes and streaks of igniting gases.

Within the summit bowl that existed before the present eruption one can see plainly through the broken nick a newly built up pile rising a hundred feet or more and largely composed of tremendous blocks of white pumice-stone which have been thrown out and accumulated in the old vent. Through these are seething wreaths of escaping steam.

Down the dreary western slope, up the valley of the Rivière Blanche, where it is lost behind the hills, one can see the smoke from another vent some 3,000 feet below the summit and not over two miles from St Pierre. When the summit sends up its great seething mushroom clouds, which float away, from this lower vent may be seen another and flimsier puff of yellowish hue which lingers near the ground. In all the eruptions that I witnessed the columns from the top of the mountain ascended, while the smoke from the lower vent of

the western slope floated off horizontally or followed the contour of the land toward the sea.

Still nearer the sea an inky-black river of mud follows the Rivière Blanche to the sea. It does not always run, but occasionally near its head great fountains of mud shoot in the air, and then the stream flows down with a single gulp.

Somewhere on the hills above Precheur there is another mud fountain, presumably at the Bains Chauds. This sends its mud down to the coast through a little stream near Precheur.

Over the dreary mud plain of the Rivière Blanche, on the margin of the sea, and upon a little islet in the sea at the mouth of the Rivière Mare, are dozens of fumaroles, each an active little steam jet sending occasional puffs into the air.

Around on the northern slopes of the mountain near Ajoupa Boullion, on the road from Basse Point to Morne Rouge, there is another mud vent which flows great streams of that material down to Basse Point, which is slowly being buried beneath it. Still to the eastward is the mud crater of the La Falaise. The latter is situated to the east of the summit, and was first seen by Mr Clerc the same date as the explosion of May 20, although it may have existed some time before. It occurs in the bed of the river itself, and while the river still flows below it, it has ceased flowing above. The water of the river is boiling and full of mud.

The dates at which these mud eruptions began cannot be stated, nor is it material, further than to say that most of them were from old thermal sources which had long been known to exist upon the island, and that they were a part of the same general phenomena of an ascending molten column of magma beneath the dome of Montagne Pelée, which, upon coming in contact with the earth water, was converted into lapilli, at the same time changing the water into steam, which forced the combined product of the steam and magma (mud) up old vents which have probably existed from time immemorial.

Clouds of lapilli and steam were noted on April 25 coming from the summit crater, and on April 27 molten matter was observed in the lower crater, L'Etang Sec, midway between the summit and the mouth of the Rivière Blanche, on the western side. These clouds of eruption occurred intermittently, with increasing size and magnitude, until May 8, the date of the great catastrophe, and are still continuing at frequent intervals, the reports having announced similar eruptions as late as June 20. About May 1 the streams radiating out from Montagne Pelée began to increase in volume, and their waters were darkened with lapilli. On May 3 a great torrent of liquid mud flowing down the Rivière Blanche showed that the mountain was erupting mud as well as lapilli and steam. The intense odor of sulphur which permeated the landscape also showed that sulphurous vapors were being ejected.

The volcano has continued working since the deadly eruption on the morning of the 8th of May, just as it had been working before. The volcanic forces continue to exhibit themselves, and are probably still in operation at this writing. There is no complete record of the eruptions. Only those which send a cloud over Fort de France, or which are observed by visitors to St Pierre, are noted.

On May 12 a great black canopy of smoke continued to rise from Mont Pelée, and spread out over the sky to the horizon, causing darkness even in the middle of the day.

On the morning of the same day, at 11.30 a. m., a cloud of smoke rolled down north of St Pierre into the sea, and was witnessed by the people on the tug *Potomac*. This cloud was timed, and came down the mountain about two

miles in three minutes, and was witnessed by the people of the *Indefatigable* and the *Potomac*. Mr Richard Kalisch, an eyewitness, showed me photographs of this cloud from which I made a sketch.

The most serious recurrence of eruption was on the afternoon of May 20, about 5.15 a. m. A cloud floated over Fort de France and caused an exodus of the people from that city. This eruption of Monday, according to Engineer Evans, who was in the hospital at Fort de France, lasted until daylight, and was accompanied by many detonations. Showers of stone the size of a hen's egg fell upon the hospital. The falling sounded like hail, and tore the leaves from the trees. These stones, as I ascertained by personal collection the following day, were old crystalline rock of the mountain and not pumice.

Victor stated that this eruption of May 20 was accompanied by total darkness over his point of view, Deux Choux, after a great explosion of flame, one-half of which went up to heaven and the other half toward St Pierre, just as the clock was striking 5 a. m. Lieutenant Gilmore, executive officer of the *Cincinnati*, who is so well known to the American people by his experience as a prisoner among the Filipinos, saw the cloud which rolled over Fort de France. He states that the stones which fell on the deck of the *Cincinnati* were so hot that they burned the awnings on the cutter. These came down like hail. Lieutenant McCormack, of the *Potomac*, stated that a slight wave surf following the eruption was felt in the Bay of Fort de France on the 20th of May, making a peculiar roll of surf. He also estimated that the fall of ejecta averaged 376 tons to the square mile.

According to many, this eruption still further destroyed St Pierre, leveling the remaining walls almost to the ground and burying the dead in the streets beneath a new shower of lapilli. A self-recording barometer at Fort de France also made a notch at the time of this explosion.

On May 25 I witnessed a frightful summit eruption from Fond St Denis. This was accompanied by lightning effects and what I believe to be the ignition of gases. An account of this eruption was described in the New York *Herald* of Sunday, June 8, by Mr Morse.

May 29, at 8 p. m., while on board the French steamer, the captain of the French steamer *D'Assas* came aboard and told Admiral Servan that he had just witnessed an overflow of incandescent lapilli from the crater rim.

On May 30, at 1.45 p. m., the cable *via* Puerto Plata broke again. Almost simultaneously vast quantities of mud flowed out of the northern crater and torrents of it invaded the plateau of the Vive plantation. This was the last bit of news I received on the *Dixie* from Consul Ayme as we weighed anchor for the United States.

Reports of eruptions have continued up to the last few days, and will probably continue for an indefinite time, until Pelée's vents once more clog up and the surface manifestations gradually diminish until the mountain sleeps again.

CONCLUSIONS

THE GEOLOGICAL LESSON

It is now evident that the destruction of St Pierre, viewed from a broader standpoint than human disaster, was but an episode in a group of general phenomena constituting the 1902 eruption of Montagne Pelée, and that the eruption of 1902 is but an episode in a series of events which have been taking place through long epochs of geologic time. Let us, then, forget, if possible, for a moment, the great catastrophe, and consider the phenomena as a whole.

1. That Montagne Pelée is one of the chain of ancient volcanic mountains, dating from Tertiary time, rising to a height of 10,000 feet above the ocean bottom along the interior side of the semicircular ridge across the entrance of the Caribbean Sea.

2. That the volcanoes of this ridge have been successively forming on its western side.

3. That the material, like that of the Cretaceous volcanoes of the Great Antilles, is entirely andesitic.

4. That the eruptions, especially of the later periods, have all been of the explosive type, unaccompanied by lava flows.

5. That the historic eruptions have taken place between long intervals of solfataric quiescence.

The geology of Martinique, as outlined, shows that Pelée is an old volcano, and that the present eruptions, instead of being sudden and a new phenomena, are but the maximum of a series of solfataric conditions which have continued through a long interval of geologic time. The eruption of 1851 produced similar phenomena of ash, mud, and steam ejected from the same vents, and affected a similar area. The geological structure of the mountain of Pelée shows, in its layers of mud, pumice, and tuffs, that these processes have been going on at long intervals from time immemorial. The first important deduction, then, is that the present eruption of Pelée is the repetition of events which have taken place time and time again at the same locality, and that the mechanism of the volcano is all old and prehistoric—the same central crater and lateral vents. So far as recorded, the volcanic mechanism of Pelée is the same as it was at the date of its discovery in 1894. No new craters have been formed, but merely old craters reopened. The principal feature of this mechanism is the crater of Montagne Pelée—simply a conical chimney leading from the hot magma of the earth and built up of its own ejecta. This chimney is a vertical tube extending downward to the interior magma, which ascends as a great column of molten matter. The bowl or crater of Pelée summit is the top of the chimney.

FEEBLENESS OF THE PHENOMENA

The fact that there were no serious earthquakes shows that the explosions within the crater were not exceptionally severe; in fact, not as severe as many which have taken place within the Antillean vents, with deadly earthquake effects, without causing eruptions. No evidence has yet been deduced showing that the present eruption was preceded by or has resulted in any serious openings or fissures in the sea bottom, which could have caused it by the sudden letting in of the waters; neither is there, in the structure and geographical position of the oceanic Caribbee Islands, any condition which enables us to hypothesize a deposit from sedimentation which would produce weight resulting in the creation of such fissures.

The conical configuration of the mountain; the repetition in geological time of the eruptions at the same locus; the absence in the structure of the island of conspicuous volcanic dikes and sills; the failure of other and more conspicuous solfataric vents along the Caribbee chain to erupt, indicate that the shape of the ascending magma is cylindrical rather than elongated, as would have been the case had it arisen along the fissure.

The eruption of 1902, which is still in progress, has been one of progressive intensity for an unknown period of time. The waters of the L'Etang de Palmiste in the top of the crater bowl have been warm for several years, and as far back as May, 1901, sulphurous fumes and vapor were noticed escaping. Conspicuous activity suggestive of intense erup-

tivity was first observed in the middle of April, 1902. These phenomena were at first slight tremors which shook the dishes on the shelves in the house of Mrs Prentiss, wife of the American consul at St Pierre, and which were undoubtedly produced by the first audible explosions within the mountain from the ascending column of magma coming in contact with moisture.

RELATIONS TO THE ERUPTION IN ST VINCENT

The synchronism of this eruption with that of St Vincent, a hundred miles distant, and volcanoes of a similar explosive andesitic character in Central America, to say nothing of disturbances reported in volcanic area throughout the world, is strangely, almost positively, suggestive that the cause of the eruption of Pelée was not the development of a local fissure suddenly letting the water of the sea down to the depths of the hot magma, but, upon the contrary, resulted from a widely occurring disturbance within the interior of the earth's magma, which caused it to rise to meet the upper wet zone, rather than the water of the latter to descend to it, and which is as yet inexplicable.

IMPORTANCE OF ELECTRIC AND MAGNETIC PHONOMENA

Finally, accompanying this eruption were phenomena, electricity, magnetism, and gases, which, while not probably occurring for the first time, have been conspicuously brought to our attention, and may lead to important deductions upon the origin of magnetic storms and the nature of the earth's interior.

RESUMÉ

The 30,000 people of St Pierre were exterminated within a few minutes and the town set on fire by the sudden eruption of a volcanic cloud.

The fatal cloud came from the lower vent, two miles north of the city.

The vapors coming from the volcano were and are sulphurous.

There was force accompanying the eruptions of the morning of May 8 of great destructive nature, which left much evidence that the gases within the cloud exploded after having reached the air.

The summit eruptions were and are accompanied by tremendous electric (lightning-like) phenomena.

A great magnetic storm accompanied the eruptions of May 8, which was recorded at remote points, and which indicated a connection between them and the volcanic eruptions.

In connection with the magnetic phenomena, it is of interest to note that Poey has presented a table showing the relation of Antillean earthquakes and eruptions to the period of sun spots. Of 38 seismic tempests in the Antilles, 17 occurred near the maximum sunspot epochs, and 14 near the minimum. Those of 1846, 1851, 1852, and 1853 were found midway between. The maximum number of volcanic eruptions occur at the minimum of sun spots, and *vice versa*.

There is some evidence that flame is emitted with the summit explosions.

All the evidence indicates that the fatal explosions were not from the site of the old crater, which is five miles distant from St Pierre. All the circumstantial evidence and much of the direct strongly indicate that the destruction was caused by the eruption from the lower vent, about two miles above the mouth of the Rivière Blanche and some distance north of the city.

CHOICE OF THEORIES OF THE CATASTROPHE

The foregoing data and essential facts concerning the great catastrophe I have not attempted to interpret, nor do I wish

to obscure the understanding of the events by individual interpretation and hypothesis. Nevertheless, it may not be presumptuous to suggest that conflagration, death, and fatality in St Pierre may ultimately be explained by either of two theories:

1. The heat-blast theory. This hypothesis assumed that the lapilli, gases, and steam of the ejected cloud were sufficiently hot to have inflamed the city and destroyed the people by singeing, suffocation, and asphyxiation. It does not account for the forces exerted radially and horizontally, nor the flame.

2. The aërial-explosion theory. The explosion of gases within the erupted cloud after their projection into the air would account for all the phenomena observed.

The aërial explosion, if it occurred, was most probably a combustible gas, but science is still unable to state its nature. The discussion of explosive gases involves a line of scientific specialization which the writer does not possess; but as sudden and mysterious as was the great secret it has left its traces and clues which the detectives of science will follow up. Metal surfaces of objects in the ruins will be examined and analyzed for traces of sulphur and chlorides. The deposits from the numerous steaming fumaroles are already within the chemical laboratory. Even the ash and rocks of the island will be submitted to minute investigation.

And then there were those frightful lightning bolts! What of them and their igniting power?

THE RECENT VOLCANIC ERUPTIONS IN THE WEST INDIES

A LETTER TO THE NATIONAL GEOGRAPHIC SOCIETY

BY ISRAEL C. RUSSELL

TOGETHER with Robert T. Hill and C. E. Borchgrevink, I had the honor to be a member of the commission sent by the National Geographic Society to examine the results of the recent volcanic eruptions on the islands of Martinique and St Vincent. Owing to the courtesy of the President of the United States, we were enabled to accompany the U. S. S. *Dixie* on her mission of relief to the stricken islands. The *Dixie* was in command of Capt. R. M. Berry, U.S N., and as one of my primary duties I wish to convey my thanks to him and his able officers, and especially Lieut. Comdr. F. A. Wilner and Lieut. J. B. Bernadou, for their genial hospitality and never-failing desire to assist in our work.

The *Dixie* sailed from Brooklyn on the evening of May 14, and after a pleasant voyage reached Fort de France early on the morning of May 21. The time spent on the *Dixie* was most enjoyable. Among our companions were Dr T. A. Jaggar, of Harvard University, and Dr E. O. Hovey, of the American Museum of Natural History, who, like the commission sent by the National Geographic Society, had in view the study of the recent volcanic eruptions. The relief stores sent by the United States Government were in charge of

Capt. J. J. Gallagher and Capt. R. Sewall, of the Army. Connected also with the relief expedition were Lieut. J. B. Clayton, Lieut. J. R. Chusch, and Lieut. J. Riley, assistant surgeons, U. S. A.; Sergts. J. P. Edmunds, W. H. Thomas, and four privates belonging to the hospital corps of the army. With the *Dixie* went also a number of correspondents for magazines and newspapers and several photographers and artists.. The *Outlook* was represented by Mr George Kennan, the *Century* by Mr G. C. Curtis, *McClure* by Messrs A. F. Jaccaci and G. Varian, *Harpers* by Mr S. C. Reid, *Leslies* by Mr G. B. Lucky, and in addition some fifteen of the leading newspapers of the United States sent able and experienced correspondents. In the list of passengers were also included the names of Mr G. de Medeuil and Chas. Van Romondte, citizens of Martinique, who had suffered severe bereavement and financial loss in the destruction of St Pierre and who kindly furnished many eager inquirers with details concerning their native isle.

ON BOARD THE DIXIE

The expedition sent on the *Dixie* was unique in several ways. It is greatly to the credit of the Army and Navy that the vessel could be coaled, loaded with 1,265 tons of relief stores, and sent rapidly gliding toward the stricken islands in the West Indies in the space of about four days. As an illustration of the spirit of sympathy and love for all mankind fostered by our great Republic, the relief expedition sent on the *Dixie* and all pertaining to it can be looked on with pardonable pride.

The voyage of the white cruiser on her mission of mercy was memorable also for the unprecedented assemblage on her decks of travelers and explorers who had visited and were familiar not only with the well-beaten highways of the world, but many of her most remote and difficult byways. Each afternoon informal lectures were given by some one from among the passengers for the benefit of the sailors, who gathered about with eager faces to learn from Hill of the beauties and mysteries of the West Indies, to travel with Kennan over the trackless snow and witness the marvelous auroras of Siberia, or explore with Borchgrevink the desolate wilds of the Antarctic continent. Walking from group to group on the deck, as the good ship glided southward, especially during the moonlit evenings, one could catch fragments of well-told narratives of life in the most remote corners of such countries as Russia, India, and Corea; or of the Philippine and Cuban campaigns and the entry of Americans into the Forbidden City. Some of our number had but recently been in Africa, and told of experiences on the firing-line of each of the contending armies in the Boer war. Others spoke of wild life in Alaska, Indian campaigns in Arizona, studies artistic or scientific in Australia, New Zealand, Hawaii, Samoa, and other places, some bearing names made familiar by recent writers in history and others so remote and wild that the general public knows not of their existence. I can truthfully say to the generous members of the National Geographic Society, that their representatives on the *Dixie* found themselves in a congenial atmosphere, and amid surroundings most stimulating to them as representatives of a great society, whose grand aim is to lead the inhabitants of the world to know the marvelous wonders of their dwelling-place.

On the morning of May 19 we passed low-lying Sombraro, a fragment of a flat, calcareous platform, and a little later sighted the island of Saba, the most northern of the volcanic Caribbees. The latter island is the summit portion of a volcanic mountain, built principally about a central crater, but judging from distant view, at least two lower craters

are still distinguishable. Later, we passed in succession St Eustis, St Christopher, etc., and as the curtain of the tropical night dropped over the wonderfully blue sea and cloud-capped islands were to the westward of Guadeloupe. I may remark here that all the islands of the volcanic Caribbees which we saw, including Martinique, St Lucia, and St Vincent, on which we landed and made more or less extended examinations, reveal in their topography the results of long erosion by heavy rains and swift, high-grade streams. The bold constructional forms of the original volcanic piles can frequently be distinguished—the rude blocks, as it were, from which the agencies of erosion have sculptured varied and bold but graceful forms. Stream erosion is the leading story recorded in the surface contours. Deep, narrow, steep-sided valleys radiate in all directions from the dominant peaks, and between them are blade-like serrate ridges. At first the topography has an unfamiliar appearance, owing to the universal mantle of luxuriant, emerald-green vegetation, but the eye soon penetrates the mask and sees the cliffs, jagged crests, and monumental forms of the rocks beneath. The islands visited are composed mostly of ejected fragments, or tuffs, interbedded occasionally with sheets of compact lava. The many and abrupt variations in the resistance of the rocks—resistance not only to the mechanical corrasion of streams, but the chemical action of warm water charged with the products of vegetable decay—find expression in the minor serrations of the thousands of sharp-crested ridges radiating from the higher peaks in all directions, and in the cliffs facing the sea. Each headland is truncated, and in many instances the progress of the ocean's waves in eating away the land is recorded by outstanding rocks and seemingly inaccessible foam-girted crags. An example of such a monument recording the former extent of the land is furnished by the historic Diamond Rock, off the south coast of Martinique.

The Lesser Antilles lie in a well-aligned chain or necklace, as our Hill has poetically termed it—unfortunately a broken necklace, when considered politically—which extends athwart the flow of the never-ceasing trade winds. The eastern shores of the island are dashed against by tireless waves. On that side the emerald of the enameled lands is divided from the glowing sapphire of the sea by a fretted band of silvery surf. On the western side of the islands the waters are usually still or broken by white-crested waves that travel away from the shore. The rise and fall of the tide is small, averaging on the headlands perhaps two feet, and for this reason the work of cutting a shore terrace is retarded. The work of the waves in modifying the coast line is most conspicuous on the side facing the trade winds, and on the eastern shore most instructive examples of towering sea cliffs, stretches of wave-smoothed beaches, and piles of wind-driven sand hidden beneath verdure attract the eye. On account, principally, of the heavy surf on the eastern side of the islands, the best harbors and the most important towns are on the Caribbean shore.

While the stars were yet scintillating in the sky on the morning of May 21 we passed southward a few miles offshore, where St Pierre lay buried beneath its pall of gray dust. As we learned later, a terrific explosion of Mont Pelée had occurred the day previous, and a second blast of dust-charged steam had swept over the dead city. Vast vapor banks shrouded alike the terrible volcano and the silent victims at its base. A few smoldering fires were visible where the once beautiful city had been, but her lighthouse was in ruins. The seeming signals were the sullen glow of her last smoldering embers.

IN THE RUINS OF ST PIERRE

The day was yet young when the *Dixie* paused in her rapid flight and dropped an anchor in the spacious harbor of Fort de France, ready to send her relief store to the sufferers on shore. Salutes were fired, official calls made by the commanders of the several warships at anchor in the harbor, and in an hour your commission was on the U. S. dispatch boat *Potomac*, traveling rapidly northward along the beautiful western shore of Martinique toward St Pierre.

But slight evidence of the considerable showers of dust and lapilli that had fallen on the island during the previous day was visible. Headland after headland was passed, each the truncated end of a sharp-crested ridge leading up to the vapor-enshrouded summit of Mont Carbet. At the mouths of the narrow, high-grade valleys red-roofed houses, villages with tapering church spires, and thrifty plantations were embowered in palms and other trees which grow densely and fail to reveal their identity at a distance.

On nearing the now widely known village of Carbet a distinct gray tone to the previously universal green of the hills told that we were nearing the source from which came the showers of dust that had fallen on the island. Soon the withered and yellow crowns of palms revealed the touch of the hot breath of Mont Pelée. Beyond a desolate ridge, steam in large volumes was rolling upward in fleecy wreaths, and beyond could be seen the gray, blasted western slope of the dreaded volcano. Rounding a promontory, the desolate, silent shore was in sight, where St Pierre but a few days before was embowered in beauty; but the eye must needs be strained or field glasses used in order to distinguish the outlines of gray ruins against the neutral background of barren cliffs where once grew the fairest gardens of the West Indies.

The *Potomac* steamed into the roadstead in front of St Pierre and was made fast to a buoy. Boats were lowered and quickly filled with men eager to study in various ways the evidences of disaster. The gallant commander of the *Potomac*, Lieutenant McCormick, every inch a sailor of the new school, gave command that all who went ashore should return to the boats when a blast from the tug's whistle should summon them, and that no one should bring off objects of value from the ruined city. I take pleasure in recording that the second of these commands was obeyed as thoroughly as the first, and, as subsequent experience demonstrated, the first command was obeyed with alacrity. Our visit to St Pierre was repeated and our exploration of the ruins extended the subsequent day, but it is not necessary at present to be precise as to dates.

While rowing from the *Potomac* to the stone quays along the water front of the dead city, we passed the indefinite spars and some of the vessels that went down on the terrible morning of May 8. No attempt had then been made to raise the sunken ships, some eighteen in number. The ruined city lay before us—silent, desolate, and gray with volcanic dust. Not a person was in sight, and not a living thing was seen during our clamber over ruined walls and through deeply débris-filled streets except the members of our own company.

It is unnecessary at this time to attempt to describe in detail the scenes that met our view as we passed in silence over the dust and rubbish beneath which thousands of human beings lay buried, as this has already been well told in the daily press. We glanced aside on passing the grim remnants of what on the fair morning of May 8 were living men and women. We could not aid in the work of cremation, suddenly abandoned the day preceding our visit, by the second great eruption of Mont Pelée, and avoided, so far as pos-

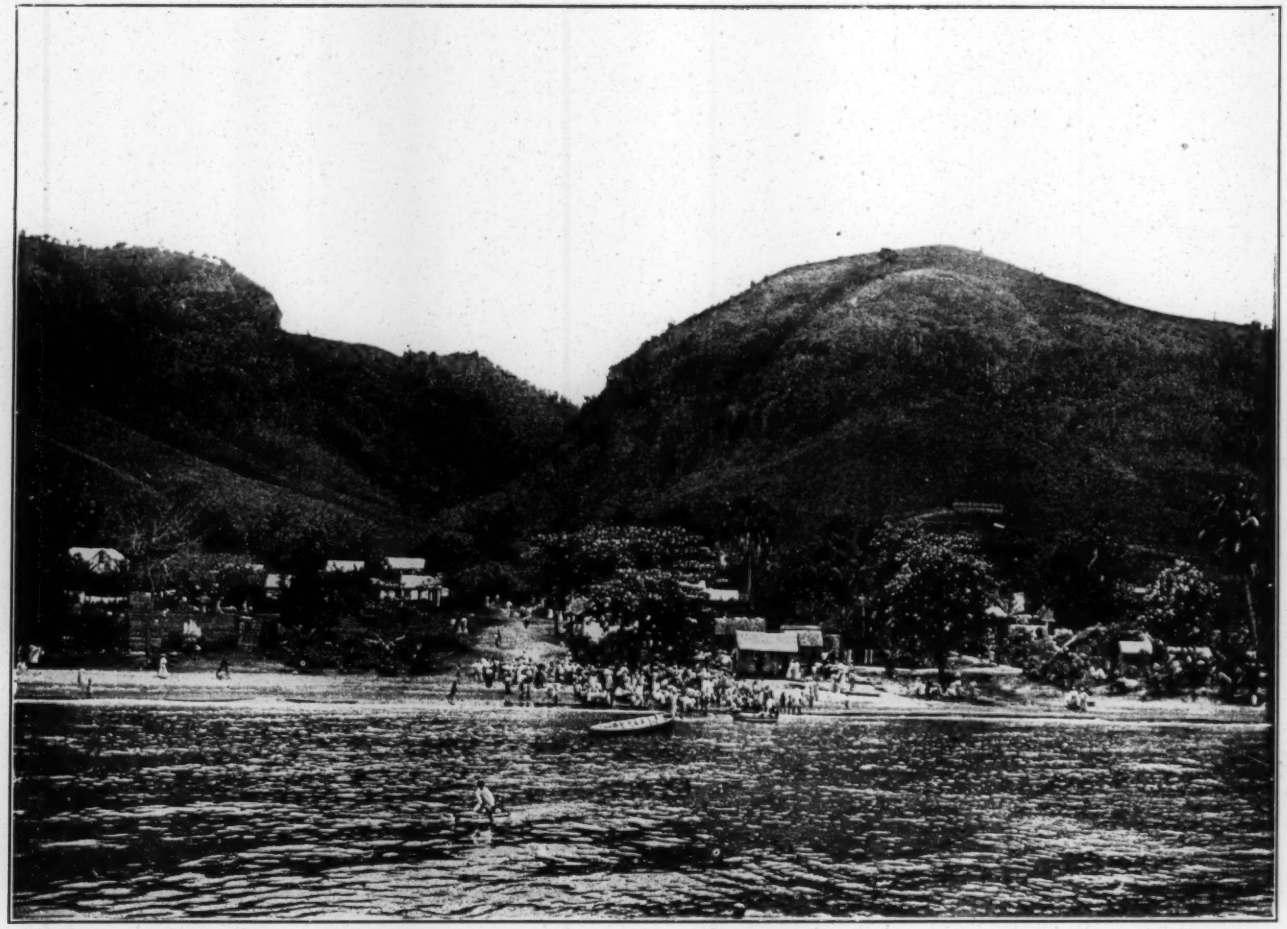


Photo by Israel C. Russell

Refugees on the Shore of St Vincent (*see page 275*)

sible, the gruesome sight still lingering. On passing to the higher portion of the city, however, where the French soldiers had not as yet performed their sanitary work, the piles of dead could not be avoided.

The best general impression of the present condition of St Pierre can perhaps be obtained from the hill at the south end of the city, termed Morne d'Orange, where formerly stood a colossal statue of the Blessed Virgin. Near the vacant pedestal of the statue is the wreck of a giant cotton tree, its broad buttressing roots still anchored in the rocks on the verge of the hill, and its blasted branches lifted like appealing arms, heavenward. From beneath the deep shade of that wide-spreading tree eyes no doubt glanced over the peaceful city, with its red-tiled roofs and many tossing palms, on the morning of the 8th of May, followed the green slope of Mont Pelée to beyond the fields of arrowroot and cane, upward to the dense tropical forest on the summit portion of the awakening volcano, to where its hot breath condensed and mingled with the vapors brought by the steadily flowing trade winds. The person who last saw that fair picture—of blue sea, animated city, verdure-covered slopes, and the vast cloud-filled sky—on the morning of my visit, lay with many others—shriveled corpses—partially buried beneath the seemingly universal sheet of gray volcanic dust. The beautiful picture had been blotted out, all except the smiling sea and the rugged mountain. At my feet lay the dead city, silent and gray. Not a green thing was in sight. Not a tree was standing, except on the far-away mountain ridge leading down to the partially destroyed village of Precheur, and even those were scorched and withered. It is difficult to convey in words the appearance of an absolutely plantless landscape, but in that triangular space, some 20 square miles in area, on the western slope of Mont Pelée, there was not a thing left alive, and not a tree left standing after the volcanic blast swept over it. Fire followed the hurricane of hot vapor, and the rain of rock dust buried what the fire left unconsumed. Never before in the history of man has such complete destruction been wrought on an area of equal size.

Gazing down into the silent streets from the heights of Morne d'Orange, I could trace their course and see the irregular plain on which the city had been built, but no conspicuous objects were in sight. Even the cathedral was indistinguishable in the universal ruin. Farther northward, where St Pierre extended beyond the bold heights on the landward side, where formerly rose the royal palms of the botanical gardens, the depth of the deposit of gray dust was such that streets were obliterated and houses buried out of sight. The reason for the deeper covering of the northern than the southern part of the city is that the former was at the margin of a sloping plateau-like surface, leading toward Mont Pelée, down which the dust was swept and piled upon the houses; while farther south sheltering heights intervened and the area from which dust could be swept was much less extensive.

I feel, however, that you are already, from your reading, almost as familiar with the desolate picture which St Pierre and its surroundings present, but may wish to ask if it is true that all the destruction was done in the space of a few minutes, and how this exceptional event in the history of volcanoes came about. The evidence of eyewitnesses who were near the border of the devastated area or on the ships in the roadstead facing St Pierre is conclusive that the 30,000 people, as the estimate is, who perished with the city died within the space of perhaps three minutes. Indeed, it seems safe to say that probably the most of them met their death

in less than one minute after the blast from Mont Pelée swept over the town. As to the precise nature of that blast, the members of your commission, I believe, differ in opinion.

It has been stated in the newspapers that the inhabitants of St Pierre were asphyxiated by noxious gases or killed by a gas explosion. My own observations and the best interpretation I can place upon the testimony of surviving witnesses favors the opinion that the general cause of death was a blast of steam charged with hot dust. Gases, probably in part inflammable, were no doubt present, as the odor of sulphurous acid was perceptible at the time of my visit; but the part that such gases played was seemingly secondary. In order to be able to judge of the conditions where everything was destroyed, it is necessary to learn what took place on the outskirts of the storm. The people on the borders of the devastated area who escaped were in some instances injured, and the injuries were inflicted by hot dust, which on touching the skin adhered and burned. These burns resemble scalds, and destroyed only the epidermis. In several such instances the hair on the burned portions was not destroyed, and where the bodies of the sufferers were protected by even light clothing they were uninjured.

Had the dust which struck the injured people been somewhat hotter their clothing would have been ignited, and if they had inhaled the hot dust death would have been almost instantaneous. The condition of the dead in St Pierre favors the conclusion that this deduction shows what there took place. While the inhalation of steam charged with burning hot dust may seemingly be accepted as the principal cause of death in the stricken city, it must be admitted that many persons were no doubt killed by falling walls, by nervous shock, etc.

The blasts which swept St Pierre on the morning of May 8, and again on May 20, passed through the city with hurricane force. This is demonstrated by the manner in which great trees were uprooted, strong masonry walls thrown down, the light-house overturned, etc. The direction in which all these objects were swept was a little west of south, or directly away from Mont Pelée. The most conspicuous evidence of the strength of the blast which wrought the mechanical destruction is furnished by a statue of the Blessed Virgin, referred to above. That statue, composed, I understand, of iron, and measuring over 11 feet in height and nearly 10 feet in circumference at the shoulders, and weighing several tons, was swept from its pedestal and carried southward about 45 feet. All the evidence collected in this connection cannot here be presented, but it indicates that the blast which wrought the havoc referred to passed over the city with full hurricane force.

EXPLORATIONS IN ST VINCENT

Space will not permit me to detain the reader longer with this preliminary account of the travels of the commission of the National Geographic Society. On leaving St Pierre at the close of our second day's visit, we returned to Fort de France, and the following day the *Dixie* sailed for St Vincent. Professor Hill remained at Martinique, while Commander Borchgrevink and I went southward to study the eruption of La Soufrière.

On St. Vincent the loss of life from the second volcanic explosions was far less than on Martinique. As has been reported by the Governor of the island, the number killed was about 1,600. Many more were injured, however, than during the eruptions of Mont Pelée. The region about La Soufrière was less densely populated than the northern shores of Martinique; there was no city comparable to St Pierre in proximity to the

Photo by Israel C. Russell

"On the slopes about us still stood the denuded trunks of palms" (*see page 275*)

volcano; but what is significant is that the people of St Vincent heeded the warnings given by their troubled mountain and many lives were saved which otherwise no doubt would have been lost.

The destruction on St Vincent was due to dust, lapilli, and stones, which fell on the land while yet hot; but a hurricane blast of steam charged with burning dust did not sweep down from La Soufrière as it did from Mont Pelée. The area on which the dust and stones fell while yet sufficiently hot to destroy the vegetation was about twice as great as on Martinique, and extends in a belt some six miles wide across the northern end of the island, leaving, however, a narrow strip of verdure on the extreme northeast coast, as is shown on an accompanying map.

The *Dixie* reached Georgetown, the capital of St Vincent, on the morning of May 23, and later the same day, through the courtesy of Mr F.W. Griffith, who had immediate charge of the distribution of the relief stores for the colonial government, I was enabled to make a trip on the steamer *Wear* northward along the west shore of the island to the devastated region about La Soufrière. A similar and more successful trip on the same boat was made the following day, during which a landing was effected at the mouth of Wallibu River and the country about Richmond House carefully examined.

While proceeding northward on the *Wear*, calls were made at the villages on the shore, where people driven from the devastated district had taken refuge, and an opportunity was afforded of seeing the stores brought from the United States actually placed in the hands of those to whom they had been sent. A similar gratifying sight was again seen a few days later at Georgetown, on the east coast of St Vincent.

On landing at the mouth of Wallibu River we saw before us a scene fully as desolate as at St Pierre. Near the shore, where a village of some 400 or 500 people stood on the morning of the 7th of May, we walked over the barren, wind-rippled, and rill-cut surface of a fresh deposit of volcanic dust and stones some 50 or 60 feet deep. This village, as in the case of the northern portion of St Pierre, was situated at the margin of a broad sloping upland, from which the débris was swept and piled deeply on the flat land to leeward. After inspecting Richmond House, a strongly built structure of stone, the partial ruin of which resulting from a hurricane a few years since had been completed by the recent eruption, I pressed on, in company with Dr Hovey and Mr T. M. McDonald — the latter the owner of neighboring estates and one of them now buried beneath the desolate covering of stones—to the bluff overlooking Wallibu River, and had an unobstructed view of the deeply filled valley of that stream and of the slopes of La Soufrière, even to its still steaming summit. Never have I gazed on a stranger or more instructive scene. We had caught Nature at work at one of her most marvelous tasks. On the slopes about us still stood the denuded trunks of palms, their sides facing the volcano stripped of their bark and scorched, showing that the wind during the storm of hot dust and stones had blown from the direction of the volcano, but not with the extreme violence so manifest at St Pierre. The hills about us were covered to the depth of three to four feet with dust and stones, then cold, and compacted so that we could walk over the surface of the layer without difficulty. One of the many interesting features to claim attention was the wonderful manner in which the layer of fresh débris had been cut by the rills originating on it from the recent heavy rains. A most beautiful system of dendritic drainage was there in active development. The rills and brooks had in many instances cut

channels through the fresh layer and exposed the cultivated soil beneath. The steep-sided trenches, with well-marked terraces, to which many tributary rill channels converged, were, in miniature, canyons like those of the Colorado region. Some of these instructive details may be recognized in the accompanying photographs.

Among the larger features of the recent changes that especially attracted attention was the manner in which the steep-sided valley of Wallibu River, perhaps a quarter of a mile broad, had been deeply filled with fresh, hot débris, and the way the displaced stream was endeavoring to regain its right of way. The valley had been filled, as estimated by Mr McDonald, to a depth of 50 or 60 feet with freshly fallen débris. Through this material, surface water was working its way, and, meeting the still hot stones and dirt, was being changed to steam, which, escaping from thousands of vents, formed white columns that rose at times hundreds of feet into the air. This wonderful display of steam jets and geyser-like eruptions, varied in grandeur with the amount of surface water present. During the intervals between the occasional heavy downpour of rain, the energy of the escaping steam would decrease, and a person could walk in safety over a miniature crater, from which steam had previously been seen to rush out as from the escape valve of a steamship, but with ten or a hundred times its volume. During a heavy shower, however, as happened at the close of my second excursion to the Wallibu region, the volume of steam became so great that the entire landscape was obscured, and the upward rolling clouds ascended for thousands of feet. On such occasions the roar of the escaping steam could be heard a mile or more. The steam jets, at times, had such energy that black columns, consisting of what may be termed mud, were shot upward like geysers, to a height of fully a hundred feet, and would play for several minutes. These miniature eruptions have been referred to, in several newspaper accounts of the strange scenes on St Vincent, as volcanic eruptions from newly formed craters; but this is a mistake, as they were clearly due to the surface waters working their way through thick beds of hot dust and stones. A similar phenomenon was witnessed by me near St Pierre, and was seen again near Georgetown, and in each instance the cause was the same.

Wallibu River, as I have stated, was displaced from its former bed by the vast quantity of débris precipitated into its channel or washed from the bordering uplands. At the time of my visit the stream was behaving in a most peculiar and interesting manner. Not only was it a stream of hot water from which steam was being given off in large volume, but, owing to the vast quantity of loose material present, was overloaded. The débris checked its flow, and for a time would hold back the water and act as a dam, the stream bed downstream becoming dry, and as the pressure of water increased, the dam would give way, and a large body of steaming water, black with material in suspension, would rush down the previously dry channel, and with a roar plunge into the sea. The stream made these pulsations at intervals, on an average, of perhaps twenty seconds, and between each swift rush of black, seething water its channel was vacant. A similar behavior of the stream near St Pierre, and also of those on St Vincent which reach the sea near Georgetown, was observed. Such examples of what may justly be termed overloaded and pulsating streams are certainly novel to students of the life histories of rivers.

From the heights above Richmond House the entire western slope of La Soufrière was in full view during our visit, and, like the corresponding side of Mont Pelée, was without life. Not

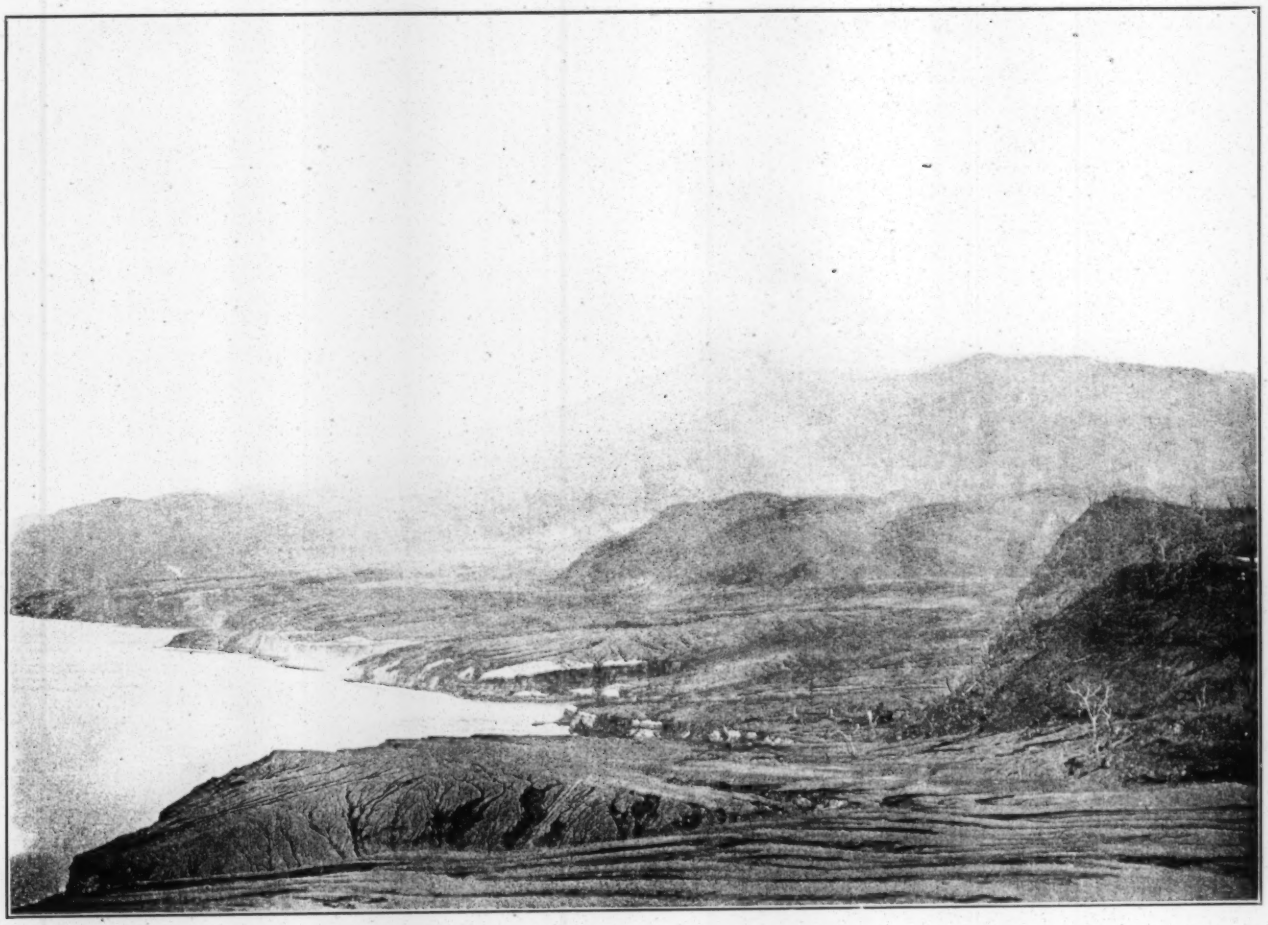


Photo by Israel C. Russell

The Devastated Slopes of La Soufrière

"Not a spray or leaf remained in all the stern oppressive landscape to suggest the loveliness that had so suddenly been blotted out" (*see page 278*)

a green sprig was visible, but utter desolation reigned. Over all the devastated region lay a thick sheet of grey débris, forming a fresh page, on which the rains had everywhere begun to write their records in the form of rill-cut channels. The newly added material, which so recently formed a part of an ascending column of lava in the throat of La Soufrière, was being rapidly removed and taking its place in the sedimentary deposits of the sea. Every downpour of rain witnessed the washing from the land of tens of thousands of tons of this fresh covering. The removal of the newly fallen material is going on with such rapidity that within a few months, or at most a year or two, it will have been completely denuded from the hills and mountain side, but will long remain in the valley. Outside the devastated area, where the fall of dust and lapilli was cold and in depth did not exceed an inch or two, it had been already, at the time of my visit, washed by rain so that the vegetation was again green, and its presence on the ground beneath inconspicuous.

Our return from the interesting excursion referred to above was precipitous, not because La Soufrière showed signs of renewed activity, as did Mont Pelée on a similar occasion a few days before, but owing to the coming of one of those sudden showers so characteristic of tropical regions. A rain squall swept over us. The wind caused the waves to rise and break in surf on the beach. Through the surf we went to reach our boats, and after some difficulty regained the *Wear*, drenched to the skin. The clothing brought by the *Dixie* was, as we understood, for the benefit of all those made destitute on account of the recent volcanic eruptions, and soon my companions and myself were arrayed in the uniform of the U. S. Army, while our citizen's clothes were drying.

On leaving the site of Richmond village the *Wear* continued northward, passing as near the shore as prudence would permit, and gave her passengers a splendid view of the blasted and utterly desolate mountains. The northern part of St Vincent is remarkably rough and possesses some unusually fine scenery. We could see far up the steep trench-like valley leading to the summit of La Soufrière, where palms formerly lifted their plumes far above the luxuriant flora of the forest, and birds haunted the shadowy recesses where orchids bloomed, but all was dark and silent. Not a spray or a leaf remained in all the stern, oppressive landscape to suggest the loveliness that had so suddenly been blotted out. At the north end of the island we passed the Fancy estate, where some 50 persons were killed on May 7, and obtained a view of the still green strip of land and projecting cape on the extreme northeast portion of the island, which, strangely as it seems, escaped destruction.

On returning to Kingstown we found the work of discharging the relief stores brought by the *Dixie* still in progress, and through the untiring courtesy of Mr Griffith I was enabled to make another trip on the *Wear* in company with Drs Jaggar and Hovey and others, this time to Georgetown, on the east side of St Vincent.

On passing around the southern end of St Vincent and steaming northward we found the usual heavy swells rolling in from the broad Atlantic, and as our course lay parallel with the waves the *Wear* rolled heavily, much to the discomfort of many of her passengers. Arriving off Georgetown, the anchor was dropped, and a landing effected by means of a strong boat which put out from the shore. The landing was novel, and to a novice somewhat exciting. Some distance out from the end of a long pier was a buoy, with a cable passing in to the shore and alongside the dock. The shore boat, manned by

Photo by Israel C. Russell

Natives of Kingstown, St Vincent

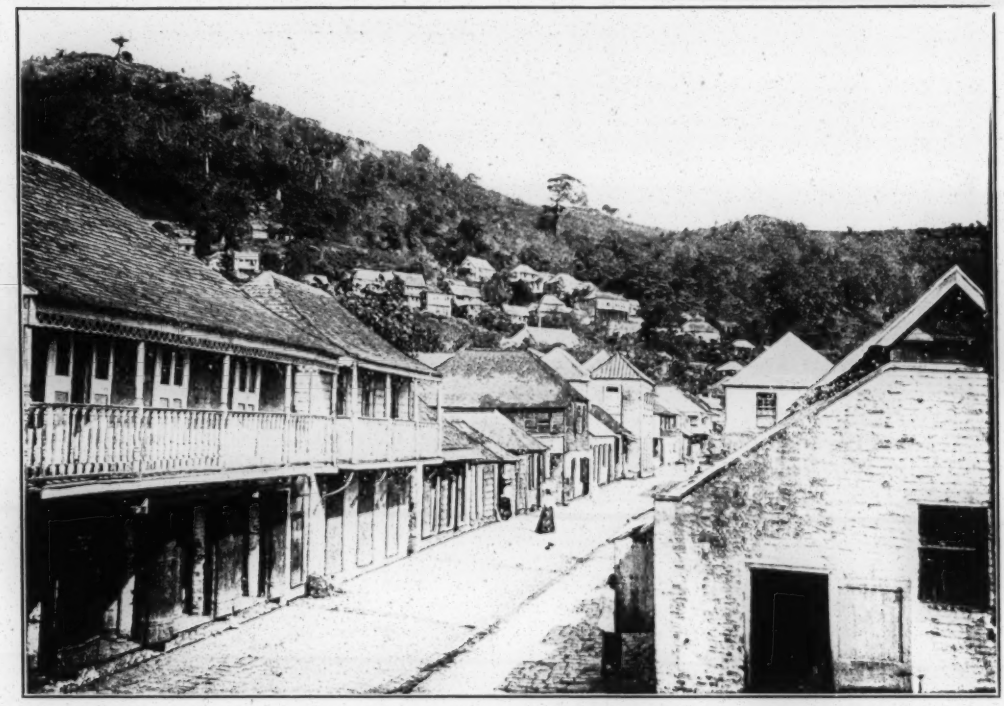


Photo by Israel C. Russell

A Typical Town of the West Indies

strong Africans who well understood the situation, was loaded with relief supplies for the hundreds of refugees in Georgetown, on the top of which as many men as wished took passage. The boat was rowed to the buoy, where, after many unsuccessful attempts, the cable leading shoreward was grasped by strong hands. The waves were there rolling heavily, surging through the timbers of the pier, and breaking with a heavy roar on the gravelly beach. By means of the cable the boat, with her freight of American codfish, American bacon, and living examples of the people from the same land, was drawn alongside the pier and held there, although surging up and down with each incoming wave. From the pier projected a rude derrick, made of boards, at the end of which was a pulley, and over the pulley passed a rope from which was suspended a rectangular box about three feet square. The derrick and cage had been made hurriedly, for the purpose of embarking some of the people injured during the late disaster, and was by no means an attractive vehicle in which to be lifted from a crazy boat. The ascent was made safely, however, but the uncertainties attending it awakened the keenest sympathy for the sufferers who descended by the same means an hour later.

From the extemporized hospital some forty of the convalescent patients, who were burned on May 7, were taken to the end of the pier, lowered into the dancing boat, and conveyed to the *Wear*, where they were taken on board by strong, willing hands as gently as the

circumstances would permit and placed on mattresses on the deck. All of the wounded were suffering from burns on the hands, feet, face, and neck, inflicted by hot dust. Of the injured on St Vincent, numbering, I believe, about three hundred, all suffered from burns of the nature just referred to, excepting a few who were struck by falling stones.

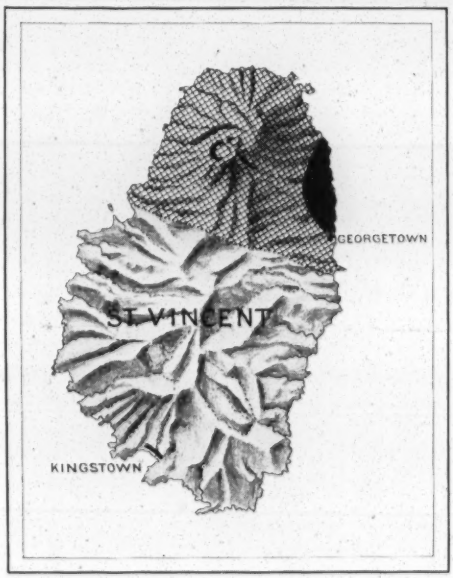
THE DISASTER AT GEORGETOWN

At Georgetown the fact that a terrible disaster had recently occurred was impressed on my mind even more forcibly than during my visit to St Pierre. The beautiful city on Martinique was so completely devastated that comparatively little remained to proclaim the tale. But for the presence of the bodies of the dead, the ruins might, seemingly, be a century old. At Georgetown, however, although the town was but partially ruined, and no loss of life occurred within its immediate borders, the dust and stones piled high in the streets, the shattered windows and roofs, the blasted palms to which the yellow leaves still adhered, the absolutely barren field adjacent, and the still steaming rivers of mud, flowing from the shrouded slopes of La Soufrière, all appealed most forcibly to the imagination, and assisted in enabling one to picture in fancy what had occurred. The people who had been exposed to the great peril still thronged the streets. In the outskirts of the town, refugees were crowded in houses inadequate for their shelter. About the door of the storehouses groups of eager applicants were receiving government aid, but no acute suffering was visible, except in the church which had been converted into a hospital. Most pathetic was the sight of the scores of injured persons, all of them, I believe, negroes, although their wounds had been well cared for by the physicians early on the scene.

Leaving the half-ruined town, with its few remaining trees, which formed a narrow strip of verdure between the sea and the desolated arrowroot field leading up to the base of the volcano, I hurried inland, in company with Dr Hovey and two negro lads, who carried our cameras, to visit Dry River and get a view of a typical example of the region on which the descent of dust and stones had been heavy. This same region was buried beneath volcanic débris in 1812, during the preceding eruption of La Soufrière, and, as I have been informed, the material which fell at that time is of the same general character as that recently showered on the island. Dry River, as I understand, derives its name from the fact that its channel was in part abandoned, owing to the quantity of débris accumulated in it during the eruption referred to. To that filling another contribution has just been made. Like Wallibu River, described above, the streams near Georgetown were working their way through deep deposits of hot débris and sending up vast volumes of steam. Our tramp took us across previously cultivated fields, now buried some two feet deep beneath stones and dust, and across small streams of warm water, which were vainly endeavoring to rid their channels of the recently added material. The view toward the volcano and northward along the coast, where several fine plantations or estates had been ruined, although depressing in the extreme on account of the devastation that had been wrought, was highly instructive as an example of volcanic action. It was in this region that the greatest loss of life on St Vincent occurred during the recent disaster. In one house which we visited 21 persons perished—all who sought its shelter. The wood-work of the house was not burned, and no other evidence remained of the death-dealing agency except the layer of dust on the floor, which was extremely fine and had a depth of about four inches. The windows of the house,

which faced eastward, were badly shattered, the glass being broken by stones which passed through them from the outside, and their frames were indented in such a manner as to show that the falling stones struck with considerable force. This interesting observation, taken in connection with other facts, shows that the stones shot upward by La Soufrière rose through the layer of the atmosphere affected by the westward blowing trade winds, and on reaching the higher region of the atmosphere, where the wind is known to be blowing from west to east, were carried well to the eastward of Georgetown, but on falling were again swept westward by the trade wind, accented, it is to be presumed, by an indraft toward the erupting volcano, and given such a slant that on striking the windows referred to they passed through and entered the rooms within.

On St Vincent the rain of dust and stones was similar to that which fell on Martinique, but in general the material is coarse. Throughout the desolated area rough, angular stones, some 5 or 6 inches in diameter, fell in vast quantities, and at a distance exceeding about five miles from the volcano dust and lapilli descended so abundantly that even at Kingstown, 12 miles from La Soufrière, the fresh layer formed was about three-fourths of an inch thick. At Chateau Bellair, on the west coast, and again at Georgetown, on the east coast, each distant about five miles from the volcano, I found the level fields coated with a new layer of volcanic débris about 2 feet thick. This is a minimum measure of the depth of the disastrous shower of stones on the devastated area, and the average thickness of the deposit is several times as great. This material, it must be remembered, came down while yet hot and many of the stones were still glowing when they struck. Not only were the stones that fell on St Vincent larger than those which descended on Martinique, but, what is also instructive, stones of two classes are conspicuous on the desolated fields. The greater part of the débris consists of gray scoriaceous andesite, and came from the columns of fresh lava that rose in the conduit of La Soufrière. This material was sufficiently cooled to become solid before it was blown into the air, and to a great extent was reduced to dust by the sudden expansion of the steam it contained. In addition to the fragments of fresh lava, the fields are strewn with angular masses of older and much more compact rock, which was torn from the walls of the conduit of the volcano by the uprush of molten material and steam and blown high into the air. These fragments of old rock



Sketch Map Prepared by Israel C. Russell Showing Zones of Devastation in St Vincent

The black area is the region of greatest loss of life; the black and dark areas are the zone of total destruction. In the light area the vegetation was not injured except by light shower of volcanic dust.

Photo by Israel C. Russell

A River of Mud Pouring from La Soufrière

Photo by Israel C. Russell

Ruined Estates near Georgetown, St Vincent (*see page 282*)

are much more dense than the accompanying fragments of fresh lava and retained their heat longer. Those that fell on the desolated area were still red hot when they struck the ground and capable of causing the ignition of houses, etc. Where the hot stones accumulated about tree-trunks the wood in many instances was completely changed to charcoal. This material at the time of my visit to Georgetown was being gathered by the inhabitants in considerable quantities and used for fuel.

This brief account of the material which fell on St Vincent will, I think, show the main cause of the loss of life and the destruction of houses, vegetation, etc., on that island. The majority of the people killed, as on Martinique, in the opinion of physicians and others early on the scene, lost their lives from the inhalation of hot dust and being scalded by steam charged with burning dust. On the outer margin of the region of destruction the steam cloud seems to have condensed to scalding water, which was thick with dust and formed a hot mud that adhered to everything it touched. Casualties also resulted from the rain of falling stones, and, as has been frequently stated, lightning from the volcanic cloud was intense and frequent and is supposed to have caused many deaths.

After returning on the *Wear* to Kingstown, where the *Dixie* still lay at anchor, visits were made to interesting places on shore, including the beautiful and well-kept botanical gardens in care of Mr Henry Powel. Early on the morning of May 29 the *Dixie* started for Port Castries, St Lucia, arriving there about

noon the same day, and the following day returned to Fort de France. On May 31 the good ship sailed for home, bearing, of your commission, Professor Hill and myself, Commander Borchgrevink having previously started northward on a passenger steamer.

The morning we bade good-bye to Consul Ayme, at Fort de France, dawned unusually fair. There was not a cloud in the sky except the vast columns of steam rising from the still active crater of Mont Pelée, which rose, as determined by angulation by Lieutenant Bernadou, to a height of 15,000 feet. On passing the site of St Pierre we had a last but distant view of the dead city. At the end of a pleasant homeward voyage the *Dixie* once more dropped her anchor in the harbor of New York on June 6.

This hasty letter I trust will serve to show the members of the National Geographic Society, at least in a general way, the nature of the observations their agents were able to make; but I trust it will in time be followed by a critical discussion of the very characteristic explosive volcanic eruptions which desolated such large portions of the otherwise charming islands we visited.

UNIVERSITY OF MICHIGAN,
June 20, 1902.

VOLCANIC ROCKS OF MARTINIQUE AND ST VINCENT

COLLECTED BY ROBERT T. HILL AND ISRAEL C. RUSSELL

DESCRIBED BY J. S. DILLER

SOON after the disaster of St Pierre the U. S. Weather Bureau sent to the Geological Survey for examination a bit of volcanic dust collected May 8, 1902, aboard the steamship *Coya*, 185 miles southeast of Barbados. To this was added later some of the volcanic sand which fell on Barbados, and the source of the material, whether from la Soufrière, on St Vincent, or Mont Pelée, on Martinique, both of which were in eruption about the same time, was a matter of much interest. Therefore when I received from Professor Hill for study the material which he collected at Martinique during his investigations for the National Geographic Society, I anticipated much pleasure in searching for the source of the dust.

Professor Hill's collection embraces 33 specimens; 30 came from Martinique and 3 from St Vincent. Of the Martinique specimens, 18 resulted from eruptions long antedating the present volcanic activity, 6 are ejecta of recent date, and 6 are "fumarole deposits" on the slopes of Mont Pelée.

The rocks of Martinique are remarkably simple, and belong to well-marked types of andesite, with normal variations representing traces of earlier conditions deep within the earth. The great volcanic belt along the axis of the two continents from Cape Horn through the Americas to Point Barrow is composed largely of this kind of volcanic rock, which indeed gets its name from the Andes Mountains, where it was early discovered.

In the prevailing rock of the collection hypersthene is the characterizing ferromagnesian silicate, and it is commonly associated with some augite. In closely allied specimens hornblende comes in

and increases until in a few of the specimens it characterizes the rock as hornblende andesite. The hornblende is always of the deep brown, strongly pleochroic variety, with rounded black border, which indicates that the hornblende during the later portion of the molten stage of the lava was undergoing resorption. Next to magnetite hornblende is among the earliest products of crystallization in the magma, as it rises by eruptions from deep in the earth toward the earth's surface. Arriving near or at the surface, where the conditions of pressure and temperature have greatly changed, hornblende is no longer stable, and is gradually attacked and resorbed by the magma, to crystallize out upon final solidification as pyroxene either as augite or hypersthene. While it may not be asserted that all the hypersthene andesites of the collection once contained hornblende, it is certain that some of them did, and that if the molten condition had continued long enough after reaching the surface all the hornblende would have disappeared.

Arranging the andesites according to their characterizing ferromagnesian silicates, there are about a dozen hypersthene andesites, several of which contain augite and a few hornblende. There are two hornblende andesites carrying more or less hypersthene. The hornblende andesite is associated with hypersthene andesites, with and without hornblende among the lavas of earlier eruption. The product of the late dsetructive outburst is hypersthene andesite.

EARLIER VOLCANIC ROCKS

To illustrate the products of earlier volcanic activity on Martinique previous to the eruption of May 8, 1902, examples were collected of building stones in St Pierre (Nos. 6, 7, 8, 11, and 13), building stones in and near Fort de France (Nos. 9, 12, and 15), and from Font St Denis (Nos. 10 and 14). The other specimens embrace boulders from Precheur (No. 1), fragments from Fumarole Island, mouth of Rivière Blanche (No. 2); Carbet Peak (Nos. 3*a* and 3*b*), Pitons, Mount Carbet (Nos. 4 and 20), and St Pierre (No. 5), and black sand of Beach Precheur (No. 31).

Hypersthene Andesite. — Specimens (No. 1) bearing the label "Precheur boulders, old rock," are good examples of hypersthene andesite. To the naked eye the rock looks uniformly gray, and only on a second closer look one perceives that it is peppered full of small crystals. Many are black, but most are white.

Under the microscope in thin section these crystals stand out more conspicuously in a gray groundmass, and the structure is microporphyritic. The white crystals are plagioclase, the dark ones are mostly hypersthene, with some augite and numerous grains of magnetite. The plagioclase in transmitted light generally becomes clear and colorless, and between curved nicols shows lamellar twinning. Some are full of inclusions arranged more or less clearly in concentric shells of crystal growth. The angles of extinction of the plagioclase suggest that it is a lime-soda feldspar approximating the composition of labradorite.

The hypersthene occurs in small 8-sided prisms, in which the four predominating planes are pinacoids. It is strongly pleochroic yellowish to greenish, and has parallel extinction, distinguishing it from the greenish augite, which is not pleochroic and has a large angle of extinction.

The groundmass in which all these crystals are imbedded is dark gray, and contains a multitude of embryonic crystals, chiefly, if not wholly, of the minerals already mentioned, swimming in a clear glassy base.

From "beach at Precheur" is an interesting specimen (No. 31) of "black

sand," marked "not of present eruption." The sand has evidently been washed by wave action, and nearly all the lighter particles, feldspar and glassy groundmass, removed, leaving the magnetite and hypersthene. A magnet separates the brilliant black magnetic grains from the more or less perfect crystals and cleavage plates of hypersthene. Most of the plates are of prismatic cleavage, but some are macropinacoidal and show a bisectrix. Neither hornblende nor augite were observed in the sand. Its composition is remarkably simple as compared with the auriferous black sand of Oregon and California.

In addition to the above, fragments of old hypersthene andesite were obtained at nine other localities. They will be briefly noted, calling attention only to points of difference as compared with that already described.

Among the "building stones of St Pierre, old rocks of the adjacent country" (6, 7, 8, and 11), there is but little variation, and that chiefly in the fineness of the groundmass. One specimen (8) differs from the others in containing some augite and having a larger than normal proportion of phenocrysts, prominent crystals. Another (No. 13) contains a trace of deep-brown hornblende. The two samples (Nos. 9 and 12) of hypersthene andesite from near the barracks, five miles north of Fort de France, marked "old rock south of Pitons du Carbet," are of the normal type.

In three of the specimens of hypersthene andesite considerable alteration had taken place. No. 10, from "Font St Denis, old rock between Pitons du Carbet and Pelée," has no hypersthene. Its place is occupied by a deep-green, more or less fibrous, platy, pleochroic mineral, with stronger birefringence than ordinary chlorite. In No. 14, from "Font St Denis, old rock covered with new ash," the pyroxene is partly replaced by the chloritic mineral noted above and surrounding calcite.

A pebble (No. 3*a*) "from a ravine on upper slope of plateau" is hypersthene, with a trace of augite and more crystalline groundmass. The hypersthene of the groundmass and some of the larger particles have altered to a yellowish-green product, in the coloring of which oxide of iron may have played a part.

Hornblende-hypersthene Andesites.— These differ from the normal hypersthene andesites in containing a small amount of brown hornblende, which has a narrow but dense black border. There are no groups of pyroxene and magnetite to represent grains of hornblende wholly resorbed, nor from the character of the border here could such be expected.

One specimen of this type (No. 15) occurs "near the barracks, five miles north of Fort de France," and the hornblende crystals in the hand specimen appear prominent enough to place it among the hornblende andesites, but in the section under the microscope it most closely resembles hypersthene andesite. Another (No. 5) is from St Pierre. It varies from the normal hypersthene andesite not only in containing a trace of hornblende, but also a grain of olivine, the only one found in Mr Hill's collection from Martinique. A good specimen (No. 2) is "old rock from Fumarole Island, mouth of Rivière Blanches," with dark felty groundmass, like many of the typical hypersthene andesites.

Hornblende Andesite. — The hornblende andesite is of a light gray color and decidedly porphyritic even to the unaided eye, with conspicuous black crystals chiefly of hornblende, attaining in a few cases a length of five millimeters. The white or glassy crystals of feldspar are less prominent, and all are imbedded in a light-gray groundmass. Under the microscope hypersthene and magnetite and also the plagioclase are seen to occur as in the hypersthene andesites, but less abun-

dantly, and the feldspar may be somewhat less calcic. The groundmass is lighter colored, filled with minute clear crystals and grains like feldspar, with few that are colored in a glassy base.

The only specimen of this type in the collection is No. 3*b*, "Carbet Peak, from a ravine on upper slope of plateau," although No. 15, from near the barracks, five miles north of Fort de France, should be mentioned here as closely related.

Dacite (*Quartz Andesite*).—One of the most interesting specimens is the dacite No. 4, "Pitons, Mount Carbet, material of peak." It is a light gray, conspicuously porphyritic rock. The light-colored phenocrysts are quartz and feldspar, the dark ones, chiefly hornblende, attaining in some cases a diameter of 8 millimeters. One apparently hexagonal scale suggests biotite. The quartz is much fractured and did not appear in the thin section, but the conchoidal fracture and uniaxial positive character of one of the glassy grains leaves no doubt as to its presence and places the rock among the quartz andesites.

The feldspars are more prominent, and the crystals broader proportionally than in the hypersthene andesites. Twinning bands are broader and sections more common in which these appear, and it is possible that some orthoclase may be present with the plagioclase. Augite and black-bordered deep brown hornblende are among the phenocrysts. The light gray groundmass is filled with small crystals of feldspar and hypersthene, with some grains of magnetite in a clear glassy base.

The dacite is much more closely related to the andesites than the dacites associated with similar andesites about Crater Lake, Oregon.

From the same locality ("Pitons Carbet, decomposed old material") comes specimen 20, which is much altered. It is friable, earthy white, spotted reddish brown with oxide of iron. Looked at more carefully, grains of quartz occur and connect it with the dacites.

Under the microscope the feldspars are found to be entirely replaced by a clear isotropic substance, and the ferromagnesian silicates are represented by oxide of iron. The groundmass has been converted into an aggregate of minute grains of a light-colored mineral like quartz or feldspar, and stained more or less deeply by oxide of iron. Several of the original quartz-phenocrysts occur in the thin section unaltered.

PRODUCTS OF THE RECENT ERUPTIONS FROM MONT PELÉE

Hypersthene-andesite Pumice. — We now come to the material which Mr Hill regards as immediately connected with the great eruption of May 8, 1902, in destroying St Pierre. It is the consolidated molten material of that outbreak. Only two pumiceous fragments (Nos. 16*a* and 16*b*) were selected from a large number for examination. They were collected "near Rivière Mare." One of them (16*a*) readily sinks in water, but the other, rounded as if water-worn, floats lightly. They differ only in degree of porosity, due to the difference in number and size of the vesicles.

The pumice is nearly white, sprinkled with small black spots, which under the microscope are found to be crystals and fragments of crystals of hypersthene and grains of magnetite. With them are clear crystals of plagioclase feldspar, probably labradorite or bytownite, and all are included in a very vesicular, dusty-looking, glassy groundmass. The vesicles range in size from less than .01 of a millimeter to several millimeters in diameter, and in shape from spherical to linear. They may be best seen with a small lens in the hand specimen, where the fibrous drawn-out character due to the expansion of the gas in the vesicles

is evident. Flow lines occur in the glass about the elongated vesicles, and its whole aspect indicates clearly that the material now glassy was once soft and fluent like paste, and while in that molten condition contained gases or vapors which expanded and formed vesicles, whose elongation took place in the direction of motion within the mass.

Here we have the seat of expansive and explosive energy, which must have played a most important part in the eruption, and we may briefly consider it, but only from a petrographic standpoint. Many of the vesicles completely closed must still contain in some form more or less of the gaseous agent that produced the vesicle, but these are almost wholly lost in the preparation of thin sections for microscopic study, and their ultimate determination must be relegated to the chemist. There can be no doubt, however, that a large part of the gaseous matter given off is steam. The source of this water and other gases contained in the molten material, magma, as it rises to the earth's surface in eruption we will not discuss, but what happens to it in the process of crystallization concerns the specimens we are considering.

Crystallization is a process of exclusion; so it happened that as the magma of Mont Pelée approached eruption crystals of magnetite and hypersthene developed with a still larger number of plagioclase, and the absorbed gases rejected in this process became concentrated in the unconsolidated portion. When the pressure was relieved the liberated gases expanded, producing the vesicles and giving rise to pumice of different degrees of porosity. Specimen 16*a*, although very vesicular, is much less so than 16*b*, for it quickly sinks in water, while 16*b* readily floats.

We can easily imagine the process of expansion to advance beyond the pumice stage even until the bubbles burst and the whole mass be blown to fragments, giving rise to lapilli and dust, of which the collection contains a number of examples. The gases filling the vesicles were the most mobile part of the mass, and like bubbles in water responding to the common impulse, moved in the same general direction, but slowly, and accumulated to form the big bubbles which produced the explosions. The eruptions of Mont Pelée, as in volcanoes generally, are a series of explosions due to the rupture of great bubbles formed from the accumulation of smaller ones like those of the pumice just described.

According to Professors Hill and Russell, there were no regular flows of molten lava from Mont Pelée during the recent eruptions. The magma was so full of absorbed gases that it was all blown out before effusion took place. The only flows were the so-called "mud flows," consisting of ejected material, lapilli, sand, and dust, so saturated with water as to flow in landslide fashion on slopes sufficiently steep.

The fragments of pumice described above probably represent more closely than any other material we have from Mont Pelée the general composition of the eruptıng magma. A chemical analysis by Mr W. F. Hillebrand is No. 1 in the table, page 291. Having considered the erupting magma, the ejected material will be taken up, beginning with that of May 8.

Sand and Dust from the Eruption of May 8.—The British ship *Roddam* was in the harbor of St Pierre at the time of the great explosion on Mont Pelée, about 7.45 a. m., May 8, and specimen 21 is dust which fell on the deck of the *Roddam* at that time.

The material was washed and separated by decantation to facilitate study. The largest particle of the specimen has a diameter of about 1.5 centimeters; but, judging from reports, much larger fragments must have fallen on deck at that time.

The material consists of small lapilli, sand, and dust ranging from the diameter stated down to particles invisible to the naked eye. Its color is dark gray. Plagioclase crystals and fragments are abundant; hypersthene and grains of magnetite somewhat less so; but at least half of the mass is dark microlitic, more or less felty, but not vesicular groundmass, often inclosing or clinging to crystals, and appears identical with the groundmass of the lavas of Mont Pelée antedating the last eruption.

There is a small amount of clear glass, which may represent the molten material in which the gas moved to accumulate for explosion, and this view is rendered more probable by the occurrence of particles of pumice similar to 16*a* and 16*b*; but it appears certain that the greater portion of the material which fell on the *Roddam* was derived from the pulverization of solid rock about the volcanic vent of Mont Pelée, and only a small part from the molten magma which was the seat of the explosion.

Sand and Dust from the Eruption of May 20.—The steamship *Potomac* was in the harbor of Fort de France, about 20 miles from the place of the explosion on the slopes of Mont Pelée, May 20. Specimens 23 and 24, which are identical, illustrate the character of the sand and dust that fell at Fort de France on that occasion. The color is pale buff gray, and the range in size of particles up to about one millimeter. Having traveled through the air much farther from its source than that collected on the *Roddam* May 8, it is much finer.

The particles are too fine for discrimination with the naked eye, but under the microscope are found to be crystals of plagioclase, hypersthene, and magnetite, mixed with a larger proportion of dark microlitic groundmass, just as in the sand from the *Roddam* of May 8, excepting that the proportion of groundmass to crystals seems larger at the greater distance, and this is to be expected, for the brittle and lighter groundmass pulverizes and floats in the air more easily than the mineral particles. Some particles of clear glass occur, but they afford not more than a trace of the magma represented by the pumice.

A comparison of the material ejected May 8 and May 20 discovers under the microscope no certain difference between the two magmas, but chemical analysis, which deals with a larger quantity than a thin section, is more likely to recognize small differences. For this reason analyses were made by Dr Hillebrand, and are given in the following table (2 and 3, p. 291).

Cinders from the Streets of St Pierre, Martinique.—One of the specimens, No. 22 in the collection, has the above label, and represents the character of the rock rain upon that ill-fated city. It contains products of both eruptions—May 8 and May 20—and is a mixture of all sizes of fragments from .001 millimeter up to two centimeters in diameter. The largest pieces, of which there are only a few in a quart of material, are composed of smaller fragments cemented by a dark substance which Dr Hillebrand has tested and found organic.

In composition this specimen is like 21 and 23, excepting that it is somewhat coarser, and contains organic matter added after the eruption. One small fragment of hornblende was fonnd and most likely came from one of the older lavas, for none was observed in the pumice.

In the rain of volcanic ejecta at St Pierre the fine and light were carried down with the larger fragments, but it is evident that much of the finer and lighter material would be shot upward by the explosions to great heights above the large, heavy fragments to be spread far and wide by upper currents. Beyond the Island of Martinique the volcanic sand and dust from Mont Pelée are not represented in Mr Hill's collection.

CHEMICAL ANALYSES

	1.	2.	3.	4.	5.	6.	7.	8.
SiO_2	61.07	60.01	63.23	55.64	52.81	57.62	.....	58.41
Al_2O_3	17.55	17.54	16.73	18.21	18.79	19.76	None.	17.85
Fe_2O_3	2.13	2.88	2.58	3.63	3.28	3.43		2.67
FeO	4.13	4.30	3.12	4.83	4.58	3.90		3.29
MgO	2.26	2.76	1.84	3.48	5.19	1.82	.....	3.61
CaO	6.28	6.80	6.01	8.14	9.58	6.25	.20	6.81
Na_2O	3.50	3.41	3.71	3.55	3.23	3.79	.08	3.77
K_2O	.98	.89	1.11	.58	.60	.71	.....	1.23
H_2O-	.23	.10	.17	.20	.20	.41	.....	.34
H_2O+	1.37	.30	.48	.54	.17	.59	.....	.86
TiO_2	.47	.45	.40	.98	.95	.87	.....	.69
ZrO_2	F't tr. ?	?	?	.....	.....	.....	.....	.....
CO_2	None.	None.	None.	None.	.....	None.	.....	.....
P_2O_5	.15	.15	.15	.11	.15	.17	.....	.24
SO_3	None.	None.	None.	None.	.33	None.	.29	.....
Cl	.....	.....	.....	.....	.14	.....	Strong tr.	....
S*	.016	Tr.	Tr. ?	.04	.....	.11	.....	.....
NiO	None.	None.	None.	None	.07	.....	.....	.....
MnO	.21	.23	.18	.19	.28	.08	.....	.....
BaO	.02	.03	.03	.03	.....	.....	.....	.....
SrO	None.	None	None.	.....	.....	.....	.....	.....
Li_2O	F't tr.	F't tr.	?	.....	.....	.....	.....	.....
	100 366	99.85	99 74	100.15	100.35	100.08		.....

* Where sulphur is reported in the above analyses the values given for FeO and Fe_2O_3 are in error by indeterminable amounts, which vary with the proportion of sulphur.

Martinique

1. Pumice from Mont Pelée, eruption of May 8. No soluble chlorides or sulphates. Analyst, W. F. Hillebrand.
2. Sand, deck of *Roddam*, eruption of May 8. Analyst, W. F. Hillebrand.
3. Sand, deck of *Potomac*, eruption of May 20. Analyst, W. F. Hillebrand.

St Vincent

4. Pumice from La Soufrière, eruption of May 7. Analyst, George Steiger.
5. Sand, Barbados. Analyst, Dr. Pollard.
6. Dust, steamship *Coya*. Insoluble in H_2O. Analyst, George Steiger.
7. Dust, steamship *Coya*. Soluble in H_2O. Analyst, George Steiger.

Crater Lake, Oregon

8. Hypersthene augite andesite. Analyst, H. N. Stokes.

Specimens were obtained from Barbados and a vessel far to the southeastward, but the character of the material, as well as its movement, noted by observers, indicate that it came mainly, if not wholly, from St Vincent, and will be described later.

"*Fumarole Deposits*," *Mont Pelée*.—The collection includes six samples of material (Nos. 25 to 30, inclusive), marked "Fumarole deposits." They are all essentially the same and may be treated together. In color they range from dirty white to buff and red-

dish brown. Under the microscope it is seen to be made up very largely of clear transparent particles, with others of light cloud appearance. They are about equally numerous. The clear ones generally show the lamellar twinning of labradorite, and look like those of the volcanic dust. The clouded material when crushed is found to be an aggregate of glass particles. Traces of hypersthene and augite and magnetite occur, but generally they appear to have been removed by the action of acid gases in the fumarole. Soluble salts may be present, but could not be determined microscopically. Mr Steiger tested one of the specimens (No. 25), but was unable to prove the presence of native sulphur. The material throughout appears to be volcanic—sand and not decomposed rock nor to any great extent deposits from the escaping gases.

Fragments from the Late Eruption on St Vincent.—Mr Hill did not visit St Vincent, but submitted a collection of three small specimens, Nos. 17, 18, and 19, of very vesicular lava from St Vincent presented him by Lieutenant Penny, of the *Dixie*. The exact location and date of eruption are not given, but it is presumed that they are products of the last eruption.

Specimen 17 is light-gray pumice, peppered with dark grains, but readily floats on water. Under the microscope it is seen to be made up chiefly of glass, which is rendered yellowish by dust-like particles. The glass is very vesicular and incloses crystals and fragments of plagioclase, with less hypersthene and a small amount of augite. Black grains of magnetite are numerous. The feldspar generally shows multiple twinning bands, but a few squarish sections are free from them. Many have well-marked zones of growth and are full of inclusions of dark glass with bubbles.

The hypersthene is strongly pleochroic from reddish yellow parallel to the lateral axes to pale green parallel to the vertical axis, and with parallel extinction. Cross-sections are nearly square, with the corners cut off parallel to the prismatic cleavage. There is but a trace of macropinacoidal cleavage.

The pale-green augite is less common and generally thicker, short prismatic crystals, with large angle of extinction.

A group of hypersthene and magnetite has for its center a lighter-colored clear grain, whose high index of refraction and birefrangence indicates olivine.

No. 18 is like 17, even to containing olivine, and contains also a trace of hornblende. In No. 19 neither olivine nor hornblende were found, and this is regarded as more likely to be the normal rock of the eruption than the others. An analysis by Mr George Steiger is given (4) in the table, page 291. Such associations of olivine is unusual, and suggests early secretions.

PROF. RUSSELL'S COLLECTION FROM ST VINCENT

Professor Russell kindly sent me three specimens, one of lapilli and two of dust, "that fell on May 7, 1902. These samples represent fresh material erupted from La Soufrière." The lapilli had the following label: "Average sample of material which well at Georgetown, St Vincent, on May 7, 1902. The material of this nature which fell ranges in size from fine dust up to rough fragments 5 and 6 inches in diameter. Mingled with this fresh lava are angular fragments of fine-grained, bluish compact rock, representing older terranes, which came down red hot and broke into small pieces on striking. Collected May 27, 1902."

No. 1. This specimen is about five centimeters in diameter, reddish brown, and spotted white and black, with crystals of feldspar and pyroxene. It is pumiceous, but not sufficiently light to float on water. Under the microscope it is mainly vesicular glass, containing

plagioclase, apparently labradorite, with augite, hypersthene, olivine, and magnetite. The single, large olivine grain is not surrounded with hypersthene, as in the other specimens, and one large crystal of augite showing lamellar twinning has an inclosed core of pleochroic hypersthene in parallel crystallographic position.

The olivine is evidently one of the early products of crystallization, and it is remarkable that three of the four specimens from St Vincent contain olivine. They recall to my mind lapilli found among those of the final eruption at Mount Mazama of Crater Lake, Oregon, where olivine is an exceptional constituent and not found in the dacitic lava of the same eruption.

No. 2. "Volcanic dust fell at Kingston, St Vincent, May 7, 1902. Collected May 24, 1902." The dust is light gray and uniformly fine, as if well assorted during its flight from the coarse material ejected at the same time. The largest particle measured had a diameter of six-tenths of a millimeter. Many mineral particles are five-tenths of a millimeter in diameter, but the average is not more than two tenths of a millimeter.

The larger particles are of dirty glass, rarely clear, and colorless and full of bubbles. Others contain a multitude of minute crystals. Those filled with these microlites are of pulverized older rock, while the dirty vesicular glass ones like the groundmass of the pumice represent the molten magma of the eruption. The latter appear to be most abundant. The greater portion of the dust is crystal fragments of plagioclase, augite, hypersthene, brown hornblende, and magnetite. Olivine may be present, but its presence could not be demonstrated.

No. 3. "Volcanic dust; surface of deposit at Richmond House, St Vincent. Collected May 25, 1902." The material is just like that of No. 2 excepting that some of the mineral fragments are larger, reaching over a millimeter in diameter, the proportion of microlitic groundmass particles greater, and a grain of olivine was observed.

SAND AND DUST FROM BARBADOS

Beside the material collected by Professors Hill and Russell on Martinique and St Vincent, several specimens of the sand and dust were obtained at greater distances from the points of eruption. Sand and dust fell at Barbados May 7 and 8, as described elsewhere,* to a depth of three-fourths of an inch. It was supposed by eyewitnesses to have come from St Vincent, distant 90 miles directly west.

The largest particles have a diameter of about six-tenths of a millimeter and average half that size. The sand is a mixture in which crystal fragments predominate over glassy particles. Plagioclase is most abundant. Hypersthene, augite, and magnetite, and perhaps traces of other minerals, occur. An analysis of material from the same fall in Barbados was made by Dr Pollard and published by Mr J. J. H. Teall.† It is given in the table of analyses. Mr J. D. Falconer in the same journal reports "a very few crystals of brown hornblende," and T. C. Porter mentions dark-colored mica and olivine, but from his description the latter is most likely hypersthene.

The presence of augite in considerable quantities supports the view expressed above that the sand came chiefly, if not wholly, from La Soufrière, on St Vincent.

DUST FROM THE STEAMSHIP COYA

The British steamship *Coya*, on the evening of May 7, encountered a shower of volcanic dust 275 miles southeast of

* Science, June 13, 1902, p. 947.
† Nature, June 5, 1902, p. 130.

St Vincent, and through the U. S. Weather Bureau the U. S. Geological Survey received the material for study. As described in *Science*,* it differs from that of Barbados only in the smaller size of particles and a relatively larger proportion of vesicular glassy to crystal fragments. The greater the distance the more important relatively becomes the vesicular glassy particles which represent the molten material of the eruption of La Soufrière, although even at a distance of 275 miles the crystalline matter is still in excess of the glassy. For the purpose of comparison, Mr Steiger's chemical analysis is quoted here with a hypersthene augite andesite of Crater Lake, Oregon, in the following table.

In an endeavor, if possible, to get a notion of the destructive gases which wrought such havoc at St Pierre, this dust was treated with a large amount of water for two hours on a water bath. An analysis of the solution thus obtained by Mr Steiger is given in column 7 in the table of analysis, indicating that the substances dissolved were $CaSO_4$ and NaCl. These are common substances in sea water, and it might be argued that they prove that sea water played an important part in the eruption. As the $CaSO_4$ is much in excess of the NaCl, they cannot be attributed directly to sea water, but more likely to the presence of the acids HCl and SO_2 in the presence of steam acting upon the lime-soda feldspar and forming the compounds recognized in solution.

The analyses of the insoluble portion given in column 6 of the table shows a considerable percentage of S present, but apparently not in a free state. It may be in the form of pyrrhotite, as suggested by Mr Hillebrand, but we were unable to prove it. Sulphides are rare in fresh volcanic rocks, although they may become common in altered forms. For purposes of comparison an analysis of a hypersthene augite andesite from Crater Lake, Oregon, is given in column 8.

In comparing these analyses it must be borne in mind that, while Nos. 1 and 4 represent the composition of the molten magma in Mont Pelée and La Soufrière respectively, the sand and dust are made up chiefly of comminuted older rocks, mixed with a portion of the lately erupted magma, and would not give necessarily reliable results as to the composition of the magma. However, it so happens that, the older rocks being of approximately the same chemical composition as that of the lately active magma, the composition averages nearly the same.

Dust spread so far and wide from the great eruption of Krakatoa was composed almost wholly of material from the molten magma of eruption. It was composed almost wholly of fragments of pumiceous glass, with a few associated crystals. Comminuted older lavas formed scarcely an appreciable part of Krakatoan dust, while at Bandai-san, Japan, in 1888, according to Y. Kikuchi,* "of lava or pumice there is no trace." All of the material ejected was decomposed and comminuted lavas of earlier eruption. The dust from the late eruption of Martinique and La Soufrière, collected at a great distance from its source, is nearly midway between these two extremes.

SUCCESSION OF LAVAS

Among the volcanoes of the western United States, especially in the Cascade Range, the succession of lava has been determined at a number of places. The earlier eruptions from the large vents are uniformly andesite of one form or another, but generally hypersthene an-

*Science, June 13, 1902, p. 947.

*Journal of the College of Science, Imperial University, Japan, vol. iii, part ii, p. 141.

desite. Later came basalts from craters about the base of the cone marking the site of the principal vent, and these were often succeeded in the principal vent by dacites or rhyolites. The series is well illustrated at Lassen Peak, less completely at Mt Shasta, but especially well in Mt Mazama, about Crater Lake. With this succession in mind we may surmise the order in the volcanoes of Martinique and St Vincent.

LAVAS OF CARBET PEAK

Upon the northern end of Martinique are two peaks which have been volcanoes, and each has its succession of lavas. Mont Pelée is still active, but Carbet, according to Mr Hill, has long since ceased erupting and is now deeply eroded.

From Mount Carbet seven specimens were obtained. Three (Nos. 9, 12, and 15) from the base are hypersthene andesite, but one of them (15) contains some prominent crystals of hornblende. From a ravine in the upper slope of the plateau comes a well-marked hornblende andesite (No. 3*b*) and a hypersthene andesite (3*a*), with a trace of augite, while the "material of the peaks" is (4) dacite; but, judging from the order among the volcanoes of the Cascade Range, the dacite is possibly youngest. Against this view, however, is the very altered condition of one specimen (20) of dacite. Considering that the volcanic vent of Carbet has furnished not only andesites with hornblende and hypersthene, but also dacite, basalts might well be expected to occur on the periphery of the same vent.

LAVAS OF MONT PELÉE

The series of lavas of Mont Pelée is less complete, but how much is due to lack of complete collection is not known. Nine specimens were obtained, among which three (2, 5, 13) are hornblende-bearing hypersthene andesites, one augite hypersthene andesite, and four hypersthene andesites, one of which belongs to the fresh eruption. The differentiation of the magma has not yet completed its cycle and there is no definite evidence that it ever will.

LAVAS OF LA SOUFRIÈRE, ST VINCENT

The number of specimens from St Vincent is small. They all belong to hypersthene andesites, but are remarkably abnormal in containing olivine. How general this feature may be can only be surmised from the number of olivine-bearing specimens. Three of the four specimens contain olivine, and the fourth may contain it also, although not shown in the thin section. The olivine was one of the early minerals to crystallize in the magma, and its occurrence here may be attributed to some peculiar condition. It recalls the more or less sporadic occurrence of quartz in basalt, which in some cases,* for example the Cinder Cone, 10 miles northeast of Lassen Peak, California, becomes a general feature of the erupted mass.

For more thorough study of the petrography of the recent eruptions of Martinique and St Vincent we must look to Prof. T. A. Jaggar, who is spending sufficient time upon the ground to make extensive and complete collections.

VOLCANIC SMOKE AND ASHES

Volcanoes are popularly referred to, even in scientific circles, as "smoking" and ejecting "ashes," but it should be understood that the terms do not express the same process or product ordinarily associated with chimneys.

Some form of organic carbon compound, as wood, coal, oil, or gas, is the common source of light and heat, and the smoke results in large part at least

*U. S. Geological Survey, Folio 13 and Bulletin 79.

from the imperfect contribution of the carbon, which is black. The heat evolved is of combustion in the oxygen of the air, and the ashes are the residue left after the separation of the carbon compounds.

In the volcanic process, however, there is no combustion of carbon, nor black smoke due to unconsumed carbon. The so-called smoke is chiefly steam clouds rendered dark or black by *lapilli*, *sand*, and *dust*, particles of solid rock matter such as those that fell at Barbados from St Vincent.

CHEMICAL DISCUSSION OF ANALYSES OF VOLCANIC EJECTA FROM MARTINIQUE AND ST VINCENT

By W. F. Hillebrand

SEVERAL of the chemical analyses of the foregoing paper by Dr Diller were only completed after his report had gone to the printer, and are hence not utilized in his discussion. There are several features connected with these and other analyses that have appeared in print which are suggestive, and it may be worth while to call attention to them at this time. The data at hand are not sufficient to warrant positive conclusions, but on their face certain probabilities appear to be indicated.

Aside from the five analyses made by chemists of the Geological Survey, the only one of much value that has come under my observation is that by Dr Pollard in *Nature*, page 130 (No. 5 of Dr Diller's table). This, while less siliceous than any of the others; and high in lime and magnesia, is in nearly every respect confirmatory of the others of like type. The exception will be referred to later (page 299). The three following analyses are incomplete and unsatisfactory, and only of service in a general way. For convenient reference they are reproduced here:

	(*a*)	(*b*)	(*c*)
SiO_2	53.34	51.60	53 40
Al_2O_3	30.68	21.12	21.00
Fe_2O_3		9.28	9 50
CaO	10.47	9.07	9.70
MgO	4.12	3.96	2.co
Na_2O	.....	0.59	2 33
K_2O	.....	0.81	0.85
SO_3	.....	0 89	0.90
S	.17		0.90
P_2O_5	Trace.	.19	0 25
Ign. loss	.....	1.20	.....
Undet	.....	1.29	....
	98.78	100.00	99.93

a. "Mineral dust from the Martinique eruption," which fell on board the *Alesandro del Bueno*, about 100 miles from St Pierre (date and location not given). *Science*, June 6.

b. Volcanic dust which fell over the Barbados on May 8. *Chemical News*, June 13.

c Volcanic dust collected from deck of steamship *Roddam* on her arrival at St Lucia. *Chemical News*, June 13.

If we consider now the six most complete analyses, those of Diller's table, they appear chemically to fall into two groups, one from Pelée, on Martinique,

the other from Soufrière, on St Vincent. The distinct characteristics are these: Higher silica and potash, with, in general, lower alumina, total iron, lime, magnesia, and titanium in the ejecta from Pelée. The difference in titanium seems to be particularly marked and characteristic. There are, however, other differences, of which the most striking is the almost complete absence of sulphur in the Pelée ejecta, while in those from the Soufrière it is a very marked constituent, both in the sulphate and sulphide conditions. Another analysis of Soufrière dust from near Georgetown, which I myself have made, but do not feel at liberty to make public yet, emphasizes this last distinction in a much more marked manner than any of those here published.

Samples 1, 2, and 3 represent the material ejected from Pelée at certainly two different eruptions, and taken from rather widely separated points. The first is tolerably compact, only slightly vesicular pumice, which still retains much of its original water, while the other two are lapilli and dust which have lost much more of their water, presumably because of higher temperature and finer comminution. No. 3, collected on the *Potomac*, at Fort de France, on the 20th of May, about 20 miles away from the seat of eruption, shows the same effects of sifting by transportation through the air that No. 6 does in the case of St Vincent dust—that is, it probably contains more of the originally molten constituents of the magma, which would be higher in silica and alkalies than the mass as a whole. Mr Steiger's tests on the dust from the steamship *Coya* show that it not only contains oxidized sulphur, but also sulphur in the state of sulphide. My own as yet unpublished analysis of dust from Georgetown shows the same, and that the sulphide is not pyrite, but one which is readily soluble in hydrochloric acid with evolution of hydrogen sulphide. When separated from other constituents its hydrochloric solution reacts for iron. It is therefore doubtless a sulphide of iron, and I regard it as probably pyrrhotite. There is no positive evidence as yet, however, that it may not be FeS. My analyses had to be made in such haste that no opportunity has as yet offered for a nearer investigation of this interesting point, the true composition of the iron sulphide.

I may here mention an analysis of dust collected at sea off St Vincent, on the S. S. *Louisianian*, an analysis of which, by Professor Carmody, appears in the *Trinidad Mirror* of May 22. For a copy of this analysis I am indebted, through Dr Diller, to the Weather Bureau of the Department of Agriculture. It is not stated in a form which can be compared with those in this Magazine, except as to the water-soluble components. These are exactly as Mr Steiger found them to be in the dust from the S. S. *Coya*, calcium and the sulphate ions largely predominating over alkali and chlorine ions.

Now let us consider the analyses, which I have denominated *a*, *b*, and *c* (page 296), in the light of the evidence thus far accumulated.

It would seem as if the soda determination of *b* of this analysis must be faulty, for of all the other analyses it is the only one which shows less than 2⅓ per cent, while six show from 3.23 to 3.79 per cent of soda. If the potash fell off correspondingly, this suspicion might not be justified; but it does not. It is of the same order as the potash of all the other analyses that show relatively low silica. To assume that the figure given for soda in *b* is correct, means that we have here a volcanic product markedly different in composition from all the others, which, taken as a whole, are essentially alike. This is highly improbable, and I feel little doubt that the value in question is erroneous. In most other respects the anal-

yses *b* and *c* might almost be duplicates, and they show the low silica and relatively high potash, as well as iron and magnesia, of the known St Vincent ejecta; likewise the high sulphur content, which is probably to be distributed between sulphates and sulphides, as in Steiger's analyses 6 and 7 and the unpublished one of my own. But *c* purports to have been collected from the deck of the S. S. *Roddam*, while *b* is from Barbados. How is it possible that two samples so very different in composition as *c* and No. 2 of Diller's table should have been ejected from the same volcanic vent at the same time and fallen upon the narrow deck of the same steamer? Even had this happened, it seems beyond the bounds of the possible that two samples taken at random should show such differences. Analysis *c* bears all the earmarks characteristic of undisputed Soufrière ejecta, while No. 2 is as characteristic of that from Pelée when compared with 1 and 3. Is it an unwarranted suspicion that the labels of the specimens *b* and *c*, whose analyses appear in the *Chemical News*, became disarranged, and that they either represent different analyses of the same Barbados dust, or, at any rate, that the *Roddam* dust is not really represented by *c*? It is hoped that this point can be made clear by the editor of the *Chemical News* and the chemist who made the analyses.

As to analysis *a*, the announcement in *Science* implies that it came from Pelée, but there is no proof whatsoever that this is so. The internal evidence of the analysis itself points most strongly to Soufrière as the source, and I shall so regard it until proof to the contrary is forthcoming. The sulphur is given in the original publication as such, without any statement as to SO_3; but, as in the case of 6, and probably 5, it may very well be in both sulphide and sulphate state.

The reason why 4 shows only sulphide sulphur and no sulphate is probably that, because of its being a lump of pumice, the sulphide was not so exposed to oxidation as that in the fine sand and dust, which must have been in full contact with air at a high temperature sufficiently long to permit of oxidation of a part of the sulphur.

If the above inferences are justified, we find, then, that while the ejecta from the two volcanoes are of the same general type and while the material from the same vent may vary in composition within limits, according as it is collected near to or far from the vent, and in coherent or finely divided form, yet there are characteristic differences by which it appears easy to distinguish the product of one volcano from that of the other.

Possibly, as I have already admitted, further careful investigation will not bear out the conclusions above suggested, but the evidences in their support are so strong at present that geologists and chemists will do well to put them to further and decisive proof.

The analyses afford room for speculation in other directions also. If it is true, as said, that the deaths in St Vincent resulted largely from strangulation from the fumes of sulphur dioxide, the source of this gas is not far to seek, for the magma before the eruption contained sulphide in quantity which, coming in contact, while red hot, with air, would be partially oxidized with formation of sulphur dioxide. In Martinique the testimony as to sulphur fumes in the dust clouds is overwhelming and the odor of sulphur dioxide was, under favorable conditions, perceptible miles at sea; but it does not appear to have been formed in such quantity as on St Vincent, and this stands in agreement with the great paucity of sulphide in the solid ejecta from Pelée, as shown by my analyses, which further accounts for the absence of sulphates in them. It is not, in my opinion, necessary to assume the

prior existence of sulphates in the matter ejected from Soufrière, for while there may have been such near the surface, resulting from fumarolic or solfataric action, the temperature at which the sulphide came in contact with air must have been sufficiently high to effect an appreciable conversion not only to the condition of sulphurous acid, but to that of sulphuric acid as well.

In making further analyses chemists should be particular to ascertain the condition of sulphur in these ejecta, and not be content to report it simply as SO_3 without further comment. Work of this kind is worth doing well, or it were better left undone.

It may here be said that in the analyses showing much sulphide the values given for the oxides of iron are only approximate. The exact error due to the effect of a more or less soluble sulphide like pyrrhotite it is impossible to gauge, though, of course, there is no difficulty in correctly ascertaining the total amount of iron, which serves as the basis for calculating the oxides and sulphides.

Earlier in this paper I alluded to one disagreement between the analyses reported by the chemists of the Geological Survey and that by Dr Pollard in *Nature* (Diller's No. 5). This relates to the presence of nickel and cobalt. Either we of the Survey have overlooked traces of nickel because of some inherent defect in our method or Dr Pollard has counted as nickel something which was not that element. I may say, as the result of our experience of many years, that such amounts of nickel as were reported by Dr Pollard are rarely met with except in peridotitic rocks, and that hundreds of analyses of almost every other kind have been made without finding such a large amount.

Dr Porter, in *Nature*, p. 131, mentions with some reserve the finding of a trace of copper in his specimens of dust from Barbados. This observation I believe to be quite correct. I also found it in the three specimens from Pelée, just as we find it in nearly every rock analysis that is made in the Survey laboratory. We seldom report it because of the opportunities usually present for its introduction from outside; but my personal belief is that it is as universally distributed through rocks as any one of the other metals, though of course in very small amounts.

Some of the points referred to in this paper may with advantage be dwelt upon at greater length in a future publication, when further data are available for examination and discussion.

REPORTS OF VESSELS AS TO THE RANGE OF VOLCANIC DUST

COMPILED BY JAMES PAGE, U. S. HYDROGRAPHIC OFFICE

FROM the log of the barque *Beechwood*, Dennison, master; Salaverry to New York:

"May 8, latitude 13° 22′ N., longitude 49° 50′ W. (Mont Pelée W. by N., 660 miles), wind E. N. E., force 4; sky overcast and tinted a buff color; fine gray dust began to fall at noon.

"May 9, latitude 14° 46′ N., longitude 51° 27′ W. (Mont Pelée W., 540 miles), wind E. N. E., force 4; sky cloudy; dust ceased falling about noon.

"On my reference to a chapter in the directory called 'An account of the fine dust which often falls on vessels in the Atlantic, and which comes from the

Desert of Sahara,' I found there was no account of its having been seen so far west, so I bottled a sample of it. On my arrival in New York and hearing of the volcanic eruption at Martinique, I concluded it came from there, although we were 600 miles to windward of that island."

From the log of the steamship *Louisianian*, Captain D. Edwards, Liverpool to Trinidad, April 25 to May 9, 1902:

"Arrived in Carlisle Bay, Barbados, May 7, at 11 a. m. (Martinique N. W., 140 miles), the weather being fine and clear. Between 1 and 3 p. m. reports as of heavy artillery firing were heard, and shortly afterward a dense black cloud appeared in the west, in the direction of St Vincent (W. 100 miles), and gradually moved toward E. S. E. At 4 p. m. the whole sky was overcast, except a low arch to the northward. At 4.30 light showers of dust began to fall, and it was so dark that lights had to be burned on the ships and ashore. At 5.30 we departed for Trinidad (Port of Spain), the weather being so dark that we could not distinguish a large mooring buoy at a distance of 40 yards. At this time the rain dust was pouring down and speedily covered the decks to the depth of a quarter of an inch. About 10 miles from Carlisle Bay the dust was so dense as to cause almost total darkness, and during this time it thundered and lightened, the lightning being of a dull-red color. From 7 p. m. to 9 p. m. the dust kept falling thickly; at 9.30 the thunder ceased and the dust showers diminished; at 11 p. m. it commenced to clear to the southward and the stars were occasionally visible. We steamed through this rain of dust for a distance of 90 miles in a direct line from Barbados to Trinidad, and at a low estimate 1 inch of dust fell on the decks. From 5.30 p. m. the wind was north, light, until 2 a. m.; after which it was S. E., gentle."

From the log of the barque *Ethel Boynton*, Captain J. W. Cates; Philadelphia to Cartagena, May 11 to June 2, 1902:

"The only thing unusual noted during the passage was the discolored water from Mona Passage (Martinique E. S. E., 400 miles) southward through the Caribbean Sea to latitude 15° N., the water throughout the stretch being of a dark grayish tint and carrying small particles, which appear to be volcanic ashes. To the southward of 15° the water assumed its natural deep blue."

From the Government Laboratory, St Johns, Antigua (Martinique S. S. E., 150 miles), C. H. G. Sprankling, observer:

"During the period of volcanic activity in the southern islands there has been nothing in the atmospheric conditions here to connect with the disturbances."

Log of ship *Lena*, Nibbs, master, Barbados to New York:

"While at Barbados a heavy rain of volcanic dust fell from Mount Soufrière (W., 100 miles) on the decks and awnings of the vessel. Seven tons of same were thrown into the hold for ballast."

Log of the S. S. *Coya*, Thomas, master, Montevideo to New York:

"May 7, 10.30 p. m., latitude 11° 23′ N., longitude 57° 52′ W. (Martinique N. W., 300 miles; St Vincent W. N. W., 250 miles). During the afternoon a heavy bank commenced rising in the north, which by 10.30 p. m. covered the whole sky. At the same time a fine gray substance commenced falling, which by 8 a. m. of May 8 covered the decks to the depth of an eighth of an inch. The wind during the incident was east, moderate; sea smooth."

Log of the barque *Eleanor M. Williams*, Corbett, master; Conetable Island to New York:

"May 8, 1902, latitude 14° N., longitude 57° W. (Martinique W., 250 miles). Fine weather, sky overcast. During the first part of the night heard a very

low moan, like thunder, in the S. W., and from 3 to 8 p. m. had a very heavy shower of ashes, covering rigging, sails, and deck. The cloud dark like a rain cloud, with changeable temperature—sometimes warm, some times cold—the sun having a reddish color and the air a dealy smell; the ashes resembling gray cement."

Log of the ship *Anaurus*, Henderson, master, Portland, Oreg., to Queenstown:

"May 9, 1902, latitude 4° N., longitude 32° W. (Martinique W. N. W., 1,800 miles). A violent vibration was felt throughout the ship for about 30 seconds, as if going over the top of something, supposed to be the effect of a submarine earthquake."

SPECIAL MAPS

PUBLISHED BY THE

NATIONAL GEOGRAPHIC SOCIETY

Map of the Philippines (5 feet 2 inches x 3 feet).
Prepared under the direction of the War Department.

Map of South Africa (46 x 33 inches).
Prepared under the direction of the War Department.

Map of Northeastern China (36 x 28 inches).
Prepared under the direction of the War Department.

Map of the Chinese Empire, Japan, and the Russian-Manchurian Railway (11 x 7½ inches).

Map of Alaska (28 x 24 inches).
Prepared under the direction of the U. S. Geological Survey.

A Series of Twelve Maps on the Alaskan Boundary Dispute.
Prepared under the direction of Hon. John W. Foster, ex-Secretary of State.

Chart of the World on Mercator's Projection (48 x 27 inches).
Prepared under the direction of the Hydrographic Office.

Map of Cuba (18 x 7½ inches).
Prepared under the direction of Robert T. Hill.

A Series of Twenty-five Full-page Charts, showing storm tracks and methods of weather forecasting.
Prepared under the direction of Dr. Willis L. Moore, Chief U. S. Weather Bureau.

BY MAIL FOR TWENTY-FIVE CENTS EACH

WASHINGTON, D. C.

Office Hours: 8.30 A. M. to 5 P. M. Telephone, Main 471

NATIONAL GEOGRAPHIC SOCIETY

OFFICES Rooms 107, 108 Corcoran Building
Fifteenth and F Sts. N. W., Washington, D. C.

ALEXANDER GRAHAM BELL . President
JOHN JOY EDSON . . . . Treasurer
W J McGEE . . . . Vice-President
A. J. HENRY . . . . . Secretary
ELIZA R. SCIDMORE . . Foreign Secretary

BOARD OF MANAGERS

1900-1902	1901-1903	1902-1904
CHARLES J. BELL	MARCUS BAKER	A. GRAHAM BELL
GEORGE DAVIDSON	HENRY F. BLOUNT	HENRY GANNETT
WM. M. DAVIS	F. V. COVILLE	A. W. GREELY
JOHN JOY EDSON	D. C. GILMAN	ANGELO HEILPRIN
G. K. GILBERT	S. H. KAUFFMANN	RUSSELL HINMAN
A. J. HENRY	WILLIS L. MOORE	W J McGEE
DAVID J. HILL	ISRAEL C. RUSSELL	GIFFORD PINCHOT
C. HART MERRIAM	R. D. SALISBURY	O. H. TITTMANN

The National Geographic Magazine is sent free of charge to all members of the National Geographic Society

---

Recommendation for Membership in the NATIONAL GEOGRAPHIC SOCIETY

The following form is enclosed for use in the nomination of persons for membership

Please detach and fill in blanks and send to the Secretary

DUES: Annual membership, $2; Life membership, $50. If check be enclosed, please make it payable to order of the National Geographic Society, and, if at a distance from Washington, remit by New York draft or post-office money-order.

.....1902

To the Secretary, National Geographic Society, Washington, D. C.:

Please propose.....

address:.....

.....

for membership in the Society.

.....

HENRY ROMEIKE'S
BUREAU OF PRESS CUTTINGS

110 Fifth Avenue, New York

Reads every paper of importance published in the United States, and through its European agencies in London, Paris, Berlin and Vienna every paper of importance published in Europe and the British Colonies. One subscription on any given subject will bring notices from the United States, and if desired also from the European papers.

WRITE FOR TERMS

Next to the Ground

BY

MARTHA McCULLOCH-WILLIAMS

"Not since the days of Thoreau has there been such an exquisite bit of nature study."—*N. Y. Journal.*

"She has freshness and aptness of diction, and a freedom from sentimentality that makes her book seem wholesome, as befits its subject."—*The Nation.*

"Mrs. McCulloch-Williams writes with overflowing knowledge and very charming[illegible] of the things of the field and the farm, and in 'Next to the Ground' we find her at her best. . . . The book is admirable, and to commend it is but a slight return for the pleasure we have had in reading it."—*N. Y. Sun.*

Net, $1.20; *postpaid*, $1.32

McCLURG, PHILLIPS & CO.

NEW YORK

"AMERICA'S SUMMER RESORTS"

This is one of the most complete publications of its kind, and will assist those who are wondering where they will go to spend their vacation this summer.

It contains a valuable map, in addition to much interesting information regarding resorts on or reached by the

NEW YORK CENTRAL LINES

A copy will be sent free, postpaid, to any address on receipt of a two-cent stamp, by George H. Daniels, General Passenger Agent, New York Central & Hudson River Railroad, Grand Central Station, New York.

The Manhattan Press-Clipping Bureau

ARTHUR CASSOT, Proprietor

NEW YORK (Knickerbocker Building) LONDON

COR. FIFTH AVENUE AND 14TH STREET, NEW YORK

Will supply you with all personal reference and clippings on any subject from all the papers and periodicals published here and abroad. Our large staff of readers can gather for you more valuable material on any current subject than you can get in a lifetime.

TERMS: 100 clippings, $5.00; 250 clippings, $12.00; 500 clippings, $22.00; 1,000 clippings, $35.00.

Seasonable Goods for Personal Comfort

We are showing hosts of things for personal and household uses especially designed to render the present season comfortable and enjoyable. A full line of necessary articles for personal comfort and use and a complete assortment of Summer Outing and Sporting Goods and accessories for outdoor and indoor pleasure

WOODWARD & LOTHROP

New York ❦ ❦ ❦ Washington ❦ ❦ ❦ Paris

The Complete Works of William Hazlitt

A LIBRARY EDITION PRINTED BY J. M. DENT & CO., LONDON
EDITED BY A. R. WALLER AND ARNOLD GLOVER, WITH AN INTRODUCTION BY W. E. HENLEY

THIS set includes Hazlitt's entire literary, political, and dramatic writings, together with his essays, miscellaneous lectures, and prefaces—in a word, all those works which have raised Hazlitt to the position of the greatest literary critic in our language. This is the first and will be the only complete collection of Hazlitt's works. The twelve volumes will be delivered to subscribers as they are published, one every two months.

Twelve volumes, cloth, 8vo, $36.00 *net*, per set (sold in sets only)
The edition for America is limited to 250 sets

McCLURE, PHILLIPS & COMPANY
141 East 25th Street, New York

JUDD & DETWEILER, PRINTERS, WASHINGTON, D. C.